US Army Corps of Engineers
Waterways Experiment Station

Wetlands Research Program Technical Report WRP-RE-15

Assessing the Functional Level of a Constructed Intertidal Marsh in Mississippi

by Mark W. LaSalle

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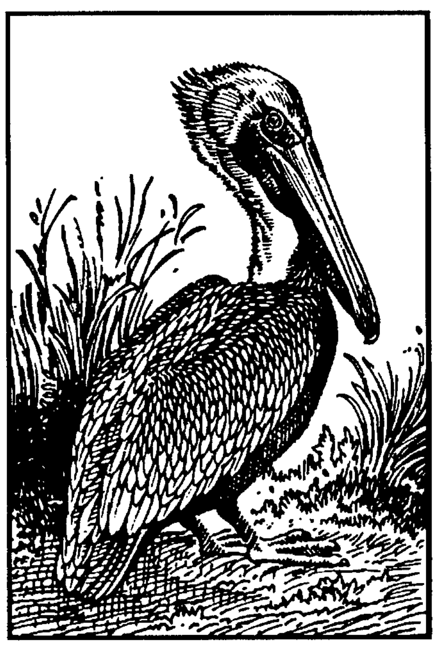


September 1996 – Final Report

The following two letters used as part of the number designating technical reports of research published under the Wetlands Research Program identify the area under which the report was prepared:

	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

Technical Report WRP-RE-15
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by Mark W. LaSalle

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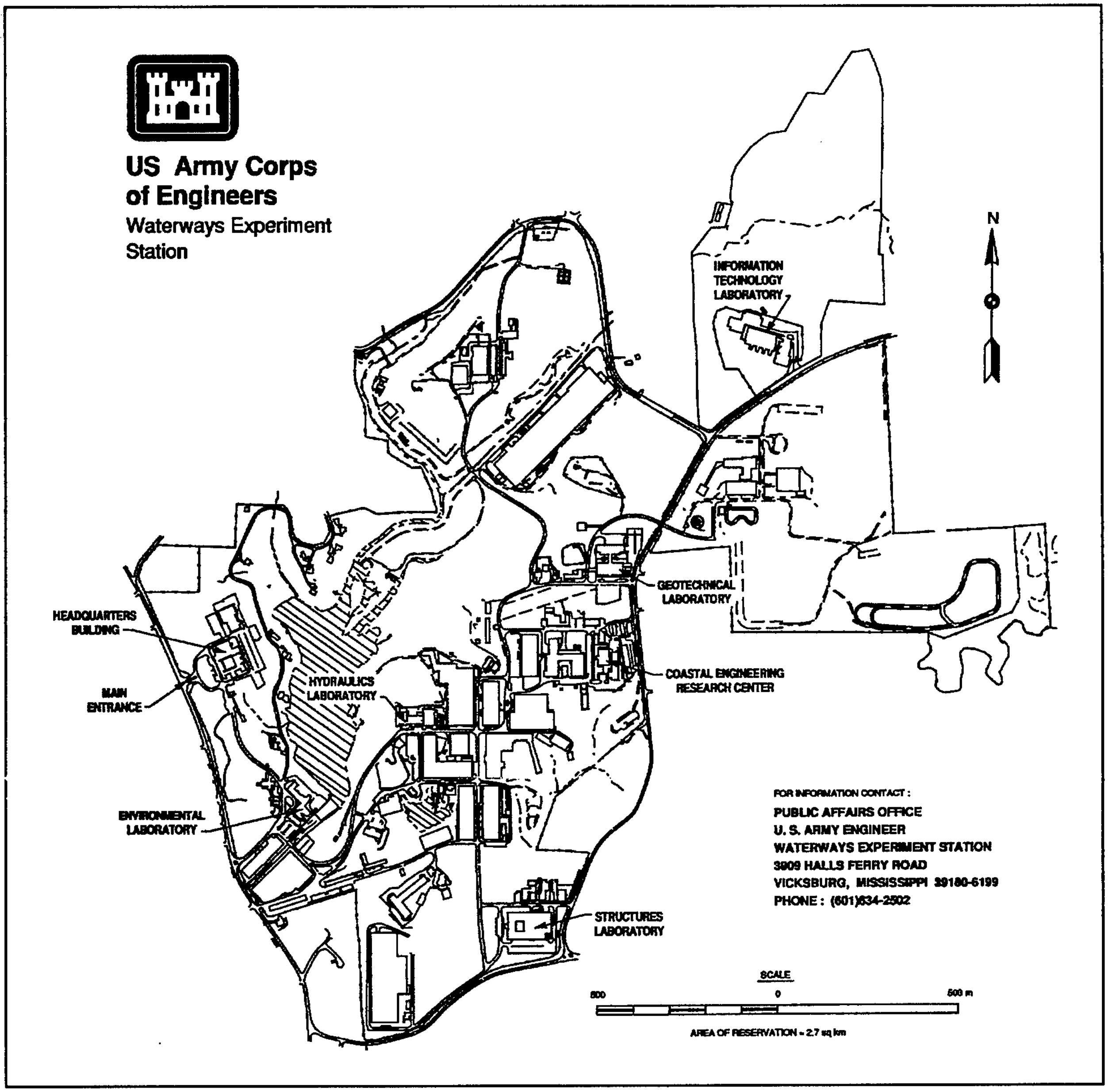
Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Monitored by U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199



Waterways Experiment Station Cataloging-in-Publication Data

LaSalle, Mark W.
Assessing the functional level of a constructed intertidal marsh in Mississippi / by Mark W. LaSalle ; prepared for U.S. Army Corps of Engineers ; monitored by U.S. Army Engineer Waterways Experiment Station.
74 p. : ill. ; 28 cm. -- (Technical report ; WRP-RE-15) (Wetlands Research Program technical report ; WRP-RE-15)
Includes bibliographic references.
1. Marshes -- Mississippi -- Design and construction. 2. Constructed wetlands -- Mississippi. I. United States. Army. Corps of Engineers. II. U.S. Army Engineer Waterways Experiment Station. III. Wetlands Research Program (U.S.) IV. Title. V. Series: Wetlands Research Program technical report ; WRP-RE-15. VI. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; WRP-RE-15.
TA7 W34 no.WRP-RE-15

Corps of Engineers Research Report Summary, September 1996

Wetland Restoration

Assessing the Functional Level of a Constructed Intertidal Marsh in Mississippi (TR WRP-RE-15)

ISSUE:

The techniques for wetland restoration and creation as mitigation often require unique and innovative work to accomplish successful mitigation. Monitoring and assessment of these man-made wetlands provide a sound basis from which to refine useful technology and build functioning wetland systems.

RESEARCH OBJECTIVES:

The study was undertaken to address some basic questions regarding man-made versus natural wetlands, specifically with regard to intertidal brackish coastal marshes. The primary objective was to evaluate physical and biotic characteristics of the wetland, in comparison with an adjacent natural wetland, including seasonal, multiyear, and multizonation comparisons.

This information is of value to field personnel who need to design and construct intertidal brackish marshes or to work with permit applicants required to carry out compensatory mitigation by constructing intertidal brackish marshes.

SUMMARY:

Detailed assessments of the major biotic components of a 25-acre (10.12-ha) constructed intertidal marsh were undertaken 7 years after it was constructed by clearcutting a pine forest and grading it down to intertidal elevation as mitigation. The elevation of the low-marsh zone in the man-made marsh was lower than the natural marsh. The man-made marsh consisted of three zonations: low marsh (*Spartina alterniflora*), mid-marsh (*Juncus roemerianus*), and high marsh (salt panne), with a centrally located tidal creek.

Despite a few physical differences in the man-made marsh and the natural marshes with which it was compared, they all supported similar vegetative, benthic, nektonic, mammal, and avifaunal assemblages. Nekton use of the man-made marsh was higher than the natural marsh in response to higher flooding frequency and duration. Sedimentation and development of tidal creeks are progressing at an expected rate, and the tidal creek is facilitating movement of nekton and other organisms across the entire marsh.

AVAILABILITY OF REPORT:

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About the Author:

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Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Restoration and Establishment of Wetlands Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32761, "Wetland Field Demonstrations and Research," for which Dr. Mary C. Landin was the Technical Manager. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for the work.

Mr. Dave Mathis (CERD-C) was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-PO) served as the WRP Technical Monitor's Representative; Dr. Russell F. Theriot, U.S. Army Engineer Waterways Experiment Station (WES), was the Wetlands Program Manager. Dr. Mary C. Landin, Wetlands Branch (WB), Ecological Research Division (ERD), Environmental Laboratory (EL), WES, was the Task Area Manager.

This report was prepared by Dr. Mark W. LaSalle, Coastal Research and Extention Center (CREC), Mississippi State University, Biloxi, MS. Messrs. John Lowe, Dan Allen, Adrian Skipper, and Steve Renfroe of the Chevron USA Products Company, Pascagoula Refinery, MS, provided background information regarding the construction and monitoring history of the study site and coordinated site access over the course of the study. Mr. Lowe arranged for elevational survey of sampling stations within the study area. Mr. Gramn Somerville, Manager of the Chevron Pascagoula Refinery, granted permission to access and study of the constructed mitigation marsh. Messrs. Erick Porche, Scott Searcy, Greg Crochet, and Mike Murphy, CREC, provided field and laboratory assistance. Ms. Jennifer Buchanan, Mississippi Department of Marine Resources, Biloxi, MS, was instrumental in facilitating the issuance of wetland permits needed to construct and operate the fish sampling devices used in the study. Technical reviews were provided by Dr. Landin and Dr. David Yozzo, Coastal Ecology Branch, ERD.

This report was prepared under the general supervision of Dr. Landin as Technical Task Manager, Dr. Morris Mauney, Chief, WB, and Dr. Conrad J. Kirby, Chief, ERD. Dr. Edwin A. Theriot was the Assistant Director, EL, and Dr. John W. Keeley was Director, EL.

At the the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

This report should be cited as follows:

LaSalle, M. W. (1996). "Assessing the functional level of a constructed intertidal marsh in Mississippi," Technical Report WRP-RE-15, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

1 Introduction

Throughout the U.S. Coastal Zone, there are numerous examples of coastal marsh habitats that have been restored or constructed as mitigation for the destruction of wetland habitat. These marshes have been established by a variety of methods and include restoration or construction of habitats in places previously occupied by wetlands, as well as in areas previously composed of upland habitats (through grade-down). Detailed evaluations of the success or failure of wetland replacements have been relatively few, however, and a number of concerns about the ability to establish viable and functioning systems persist (Minello, Zimmerman, and Klima 1987; Thayer 1987; Zedler 1988; Moy and Levin 1991; Minello and Zimmerman 1992).

Two central questions concerning habitat construction and restoration pertain to the degree to which a constructed marsh will support similar biotic components and provide similar functions compared with natural habitats, and the time required to achieve this level, if at all. Debate has also focused on the relative merits of various techniques for establishing the overall site characteristics. For example, Moy and Levin (1991) studied a constructed marsh that was established by the grade-down of upland habitat, reporting that the substrate at this site was generally low in organic content and may initially impede vegetation development. LaSalle, Landin, and Sims (1991), on the other hand, reported that many of the biotic characteristics of a marsh created through the shallow-water disposal of dredged material were comparable with those of natural marshes. Other studies (Minello, Zimmerman, and Medina 1994) have focused on design considerations that could enhance a site's functional capacity relative to selected biotic components (e.g., fisheries support).

The present study was undertaken to address some of these basic questions regarding constructed versus natural marshes by evaluating a site in Mississippi that had a unique combination of design characteristics. Plans for the marsh were developed with input from several State and Federal resource management agencies and included several innovative design factors that were chosen to increase habitat heterogeneity and to enhance fishery functional capacity. The site was relatively large (25 acres or 10.12 ha) and was constructed through the process of grading-down of upland habitat. The design included the establishment of multiple elevational zones, two of which were planted and corresponded to low and midmarsh elevational zones. The site

also included a centrally located tidal creek designed to facilitate nutrient exchange and access by aquatic organisms.

2 Objectives and Hypotheses

The main objective of this study was a comprehensive evaluation of the physical and biotic characteristics of the site compared with adjacent natural areas, 7 years after construction. These evaluations included seasonal and multiyear monitoring designed to document and evaluate trends in the continued development of the marsh. Basic hypotheses concerning the comparative quality and functional capacity of natural versus constructed marshes and the effect of the centrally located tidal creek on exchange of physical and biotic components were tested. Additional information was gathered on the effectiveness and comparative efficiency of two newly developed techniques for quantitative sampling of nektonic organisms in marshes (Kneib 1991; Rozas 1992).

The overall hypothesis tested by this research concerned the degree to which the physical and biotic attributes (and associated functions) of the constructed marsh compared with that of nearby natural marshes. Simply stated, the overall hypothesis is: "The physical (e.g., sediment characteristics) and biotic (e.g., plant and animal abundance) components of the constructed marsh are of a similar nature (i.e., qualitatively) and quantity (i.e., not significantly different) to those of similar natural marshes." Components that were evaluated included sediment texture, macrophytic vegetation, benthic macrofauna, and fish and shellfish support. A more subjective evaluation was made of mammal and avifaunal use.

The role of the tidal creek in enhancing the exchange and accumulation of organic matter and aquatic organisms and the support of benthic macrofauna was evaluated through comparisons of data collected along the course of the tidal creek. The basic hypothesis tested here implies that the creek serves to allow exchange and or support of equal kinds and quantities of these factors across the site. Many of the major biotic functions of wetlands are thought to be driven by basic hydrologic patterns, such as flooding frequency and duration, and the amount of "edge" across which materials and organisms are exchanged (Hackney et al. 1990; LaSalle et al. 1995). The rate of organic matter accumulation is also of interest given previously stated concerns about organic levels associated with grade-down sites (Moy and Levin 1991). The presence of the tidal creek should, therefore, allow for greater rates of exchange and accumulation of these materials and organisms across the site.

3 Study Site

The study site is located southeast of Pascagoula, MS, on the Pascagoula refinery of Chevron U.S.A. (Figure 1). The marsh lies adjacent to and is now part of the Grand Bay-Bangs Lake estuary that lies east of the refinery. This estuary is part of the former delta of the Escatawpa River and, as such, is a naturally retrograding delta, characterized by low freshwater and sediment input and oligo to mesohaline conditions. Twenty-five acres of intertidal marsh were constructed by excavating pine flatwood uplands. The site measures 80 m wide by 1,200 m long and includes a centrally located tidal creek that runs nearly the full length of the marsh and is connected to the tidal waters of the adjacent estuary via a previously excavated borrow channel (about 1-2 m deep). The site was graded on either side of the shallow creek (initially about 1 m deep) in order to simulate the range of elevational zones found in nearby marshes (elevations were determined and established relative to that of adjacent marshes). These included a low-marsh zone dominated by *Spartina alterniflora,* a midmarsh zone dominated by *Juncus roemerianus,* and a high-marsh/salt panne zone. The excavated material was used to create a sloped buffer zone that was planted with slash pine and live oak. The marsh was planted with *S. alterniflora* and *J. roemerianus* in their respective zones. Several additional species of plants have naturally colonized the site, including the high-marsh/salt panne area *(Distichlis spicata* and *Salicornia* spp.) and the buffer zone. The site was completed in November 1985. Subsequent monitoring consisted of yearly nonquantitative biotic descriptions and photographic documentation of overall site characteristics and covered the first 3 years after construction (Dan Allen and Steve Renfroe, Mitigation Monitoring Reports to the Mobile District, U.S. Army Corps of Engineers, 1986-88). A portion of the natural marsh located adjacent to the constructed site was used as a reference area. The sampling sites used within this marsh were located along a natural tidal creek of similar size to that of the constructed marsh. In addition to the presence of the creek, this site was chosen because of the presence of a patch of low-marsh *Spartina* of sufficient size (100 m^2) in which a flume weir could be constructed.

Initial monitoring by Chevron showed rapid natural vegetative colonization of the midmarsh and high-marsh/salt panne areas within the first year, with almost complete vegetative coverage within the first two growing seasons (i.e., 2 years). The passage of Hurricane Elana in 1985 caused erosion of sediments and associated plants from portions of the low-marsh zone. These

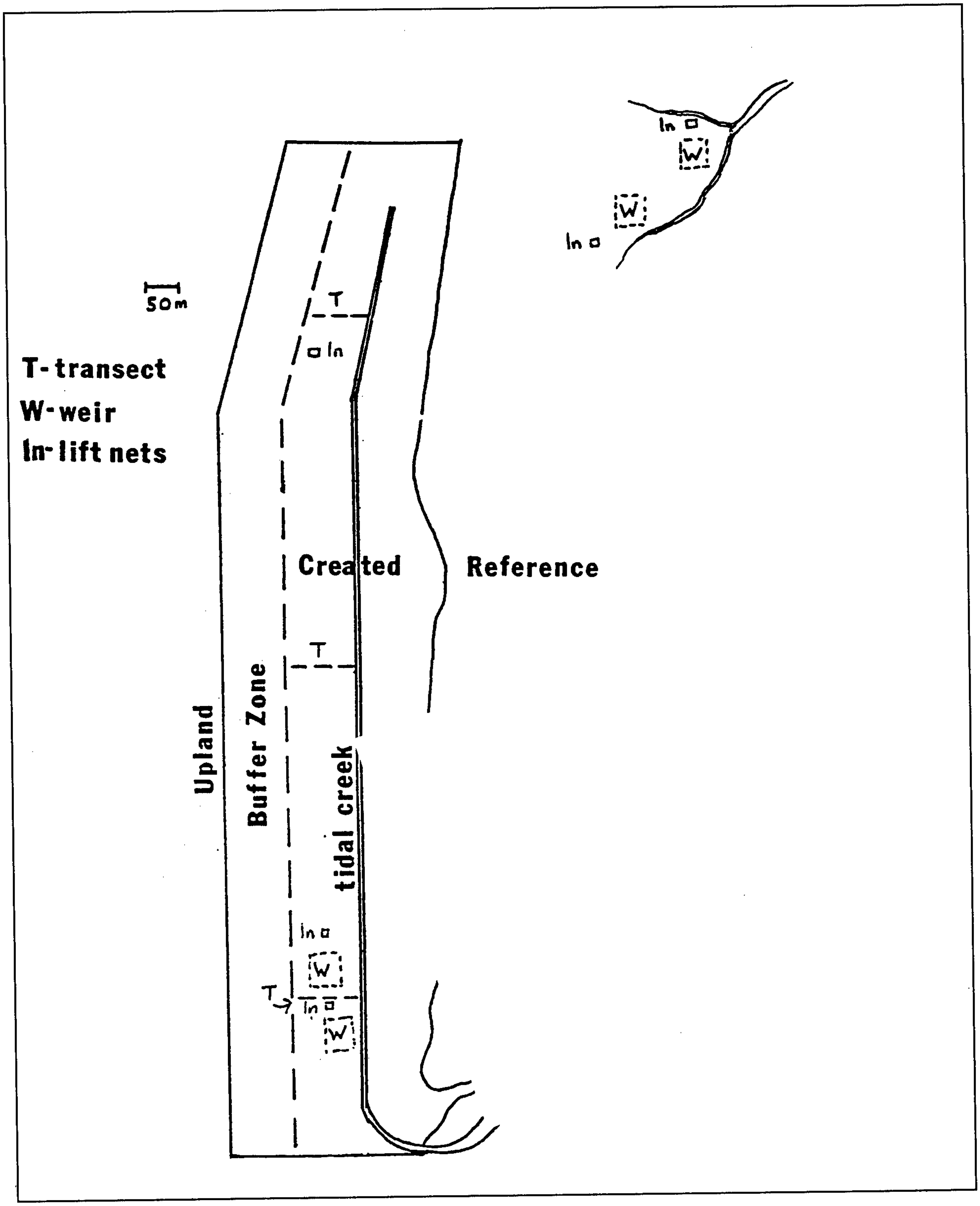

Figure 1. Diagram of constructed marsh and reference natural marsh on the Chevron Refinery southeast of Pascagoula, MS, showing relative locations of centrally located tidal creek, elevation zones, and associated buffer zone (locations of sampling transects, flume weirs, and lift nets are shown)

areas have only partially recolonized with low-marsh vegetation over the intervening years, presumably because the resulting elevation is too low to support intertidal vegetation and because there has been minimal sedimentation within these barren areas. These areas were, however, frequented by wading birds and shorebirds and presumably function as important feeding areas. The use of the constructed site by birds and mammals was also detected within the first year as evidenced by tracks across the site and by direct observations.

4 Methods

Physical components measured included elevation and sediment texture, estimated on a one-time basis. Biotic components included vegetation, benthic macroinfauna (small and large components), aquatic nekton (fish and shellfish), and bird and mammal use and were monitored on a seasonal basis, timed to correspond to peaks in either the abundance/biomass or the presence of respective components (e.g., peak plant biomass, seasonally occurring nekton). Except for large benthic macrofauna, all biotic components were sampled on multiple occasions during the period of study (fall 1992 through spring 1994). Sampling was conducted at a combination of permanent and random locations within the constructed and natural areas (Figure 1) and included strata along both vertical and horizontal axes of the constructed and natural areas. In addition to comparing the low- (*Spartina*) and mid-elevation (*Juncus*) marsh zones (vertical) in both the constructed and natural areas, sampling was also conducted along the horizontal axis of the tidal creek in the constructed site in order to evaluate the effectiveness of the creek. Sediment and nekton samples were taken from permanent sites located near the head and mouth of the tidal creek. Vegetation and macroinfauna were sampled at randomly selected points along three transects traversing the constructed marsh (head, mid, and mouth area) and single transects in the adjacent natural reference marsh. Small mammal sampling was conducted in the vicinity of the nekton sample locations; large mammal and avifaunal observations were conducted across the entire marsh in both areas. The lift nets used were placed with their centers at the same relative position within the zone as that of the nearby flume weir, which would equate to them being placed at, and sampling from, the center of a flume weir.

Physical Parameters

An initial elevational survey was conducted in both the constructed and natural areas in order to determine relative elevations for the entire area and elevations for prospective nekton sampling locations (Figure 1). Elevations were determined using standard surveying techniques, referenced to nearby benchmarks. Once the fish sampling devices were installed in the marsh, specific elevations for the center of each were determined and compared with these site-specific reference markers using simple flooding depth recorders.

Depth recorders consisted of 50-cm-long, 1-cm-diam clear plastic tubes attached to wooden stakes. The bottom end of the tube was placed 2-3 mm above the marsh surface. About 5 ml of ground cork dust was placed within the tube at low tide. The height to which the dust rose and adhered to the tube wall was recorded as flooding depth and compared with that of the nearby reference marker.

Sediment texture was determined along both horizontal and vertical axes in the constructed area and vertical axes in the natural area. Sampling locations in the constructed area included the mouth and head of the tidal creek (horizontal) and three elevational zones: low marsh (*Spartina*), midmarsh (lower portion of *Juncus*), and high marsh (interface of *Juncus* and adjacent salt pannes). Sampling in the natural marsh included corresponding low-marsh, midmarsh, and high-marsh (*Distichlis*) zones.

Sediment samples were collected in January 1993 using a 4.8-cm-diam aluminum corer. Three 5-cm-deep samples were collected from each marsh/zone. Sediment texture (percent sand, silt, clay) was determined using the pipette method (Folk 1968). Values of percent sand, silt, clay, and organic matter were statistically compared separately using analysis of variance (ANOVA) on data that were square-root transformed.

Vegetation

Vegetative samples were collected in the low-marsh (*Spartina*) and midmarsh (*Juncus*) zones of each site during respective peak biomass periods for aboveground (fall) and belowground (winter) components. Aboveground samples were collected at 10 randomly selected locations along three transects (head area, midarea, and mouth area) traversing both elevational zones in the constructed site (three samples on two transects, four on the third for each zone) and two transects (one each in the low-marsh and midmarsh zone) in the natural site. Aboveground standing live and dead stems were clipped at ground level from 0.25-m^2 quadrates, oven-dried to constant weight at 107 °C, and weighed. Data on the following parameters were also recorded: species composition, number of live stems per species, maximum stem height by species, and presence of seed heads. Samples were collected in October 1992 and August 1993.

Belowground biomass (of roots, tubers, and rhizomes) was determined from material collected in cores that were also used for sampling macroinfauna. A 9.8-cm-diam aluminum corer was used to remove a 10-cm-deep core from the marsh at each sample site (see description for the placement of each core under the section on macrofauna). Belowground plant material collected from these cores was oven-dried to constant weight at 107 °C and weighed. Samples were collected in November 1992 and March 1993. All data collected on both aboveground and belowground plant biomass was

statistically compared using ANOVA, after data were log transformed (natural log x + 1).

Benthic Macroinfauna

Macroinfaunal samples were collected in the low marsh (*Spartina*) and midmarsh (*Juncus*) zones of each site. Samples were collected at five randomly selected locations along three transects (head area, midarea, and mouth area) traversing both elevational zones in the constructed site and two transects (one each in the low-marsh and midmarsh zone) in the natural site. Two methods were used in order to better sample small (< 1-cm) and large (> 1- to 2-cm) organisms (as described in LaSalle, Landin, and Sims 1991). Small macroinfauna were sampled with a 9.8-cm-diam aluminum corer to a depth of 10 cm. Given the observed higher densities of macroinfauna associated with the presence or absence of live plant roots and rhizomes (Rader 1984; LaSalle, unpublished data), samples were to be taken in such a way to include both live plant material and adjacent bare mud in an attempt to reduce overall variation. Aboveground leaves and stems were clipped prior to placement of the corer to include both plant and bare mud areas (approximately equal surface area). Samples were washed on a 0.5-mm mesh sieve, fixed in 10-percent formalin, and stained with Rose Bengal.

Large macroinfauna (large individuals of snails, clams, and mussels not likely to be adequately sampled by a small diameter core) were hand sampled and enumerated on the mud surface and down to a depth of 5 cm from 1-m^2 plots. Fiddler crab (*Uca* spp.) burrows were also counted and used as an index of their abundance (more labor-intensive methods are required to adequately estimate their densities). Organisms from both sample types were enumerated and identified to the lowest practical taxonomic level. While the presence and identification of *Uca* spp. collected within core samples are noted, analysis of their density was not attempted. Large individuals of snails, clams, and mussels collected in core samples were similarly noted but not included in the analysis for this sample type. All data collected was statistically compared using ANOVA, after data were log transformed (natural log x + 1). Samples from each transect in the constructed marsh were considered to be independent assemblages and compared as such with that collected from the single transect in the natural marsh. Small macroinfauna samples were collected on three dates, corresponding to predicted maximal (early spring - March 1993), minimal (summer - August 1993), and moderate (fall - November 1992) periods of abundance (LaSalle and Rozas 1991). Large macroinfauna were sampled on a single date (November 1992).

Small macrofaunal assemblages from each marsh were also compared using indices of species richness (number of species from all 10 samples from each site), species equitability (Berger-Parker dominance index) and similarity (Czekanowski's and Bray-Curtis indices). The dominance index (Berger and Parker 1970), calculated as 1-d, is a measure of the extent to which an assemblage is made up of the most abundant species and ranges from 0-1; low

values reflect higher equitability. Czekanowski's coefficient of similarity (Southwood 1978) and the Bray-Curtis index (Bray and Curtis 1957) measure the similarity of assemblages based on presence-absence or abundance data, respectively. Both indices range between 0 and 1, where high values indicate high similarity.

Nekton (Fish and Shellfish)

Fish and shellfish (crabs and shrimps) utilizing the marsh surface were sampled during two major periods of the year, corresponding to predicted peak abundance of target organisms. Spring samples (March - May) targeted seasonally abundant transient species such as juvenile brown shrimp, spot, and mullet, as well as resident species such as the killifishes and grass shrimp. Fall samples targeted the seasonal occurrence of juvenile white shrimp and resident species. Samples were collected in the low-marsh (*Spartina*) and midmarsh (*Juncus*) zones of each site as well as near the head of the tidal creek in the constructed marsh (*Juncus* zone only).

Two recently developed quantitative methods for sampling nekton directly on the marsh surface were used in this study. Kneib's flume weir (Kneib 1991) collects organisms from a relatively large area (100 m^2), providing a relatively low "edge" effect for the area sampled. The size and cost of these devices, however, limits the number that can be deployed and operated. Although Rozas's lift net (Rozas 1992) samples a much smaller area (6 m^2), the nets are easier to deploy and more nets can be deployed and operated, allowing for better replication. Both types of devices employ a strategy of enclosing organisms on the marsh at high slack tide. Organisms are retrieved at low tide from a collection pit placed in the lowest point within the enclosed area. The mesh size of netting used for constructing the lift nets (1.5 mm) was chosen to be as close to that of the window screening used in the flume weir (1.0 mm) in order to avoid design bias.

A combination of these two devices was used to test the stated hypotheses of the present study. Flume weirs were used to make direct comparisons of low-marsh and midmarsh zones in each area. Single lift nets were also placed near flume weirs and used to make direct comparisons of the relative sampling effectiveness of these two devices. The role of the tidal creek in facilitating nekton use of the entire marsh was tested by deploying single lift nets at each end of the creek (using the net placed near the flume weir at the mouth of the site and a second net placed near the head of the creek). Because of the patchy nature of the vegetation in the *Spartina* zone, this comparison was made only in the *Juncus* zone. In summary, four flume weirs and five lift nets were used.

Replication (n = 2) was obtained during each sampling period by collecting samples from each device on multiple tides (i.e., days). Samples were collected over the 4- to 5-day portion of the 28-day lunar cycle during which

the highest high tides (i.e., tropical spring tides) occurred and reached similar tidal height. This period of the lunar cycle was chosen to represent maximal possible tidal flooding and access by nekton across both elevational zones of the marsh. Preliminary data showed that both sampling methods required a 2-day set in order to recover a sufficient proportion (> 80 percent) of organisms trapped within each device once they were set. A replicate sample, therefore, consisted of the combination of organisms collected over a 2-day period, which corresponds with two tidal events (one high tide per day). The sampling pits were emptied at low tide on each day. This schedule allowed for two replicate samples over the 4- to 5-day spring-tide period during each sampling period. All organisms collected were identified to species and enumerated. All data collected was statistically compared using ANOVA, after data were log transformed (natural log $x + 1$).

Mammals and Avifauna

The use of the marsh by mammals and avifauna was determined through a combination of direct collection for small mammals (i.e., trapping), visual searches for signs of large mammal presence, and direct sighting of birds. Observations and sampling were conducted during the same periods of the year as for fish and shellfish. Small mammals were collected using oat-baited Sherman traps deployed on tethered wooden boards placed in the vicinity of each flume weir (November 1992 and March 1993). These data were used to make comparisons of the use of the low-marsh and midmarsh zones in both sites. Five traps were deployed in each of the four flume weir locations. Traps were checked daily over a 3-day period during each sampling period. Bird observations were made through a combination of direct sightings and recognition of calls (particularly for the reclusive clapper rail) from the vantage point of the flume weirs in each area. Walks along established transects in each marsh zone were made to search for indicators of bird or large mammal presence (e.g., nests, droppings, tracks). These observations were made over a 30-min period on each visit to the site.

5 Results

Physical Parameters

Elevations across both sites (as determined for each fish sampling device) are shown in Table 1. Within the natural marsh, there was a 7.6-cm difference between the *Spartina* and *Juncus* zones, whereas, there was as much as a 28.0-cm difference between zones in the constructed marsh (as measured from the reference marks). The difference in elevation between zones in the constructed area was somewhat less (20.6 cm) as measured at the center of each flume weir and reflects a somewhat more average elevation within the *Spartina* zone of this area: the reference mark was located closer to the creek edge and not near the middle of the zone. The *Spartina* zone of the constructed site was also much lower (16.6 cm) than that of the same zone in the natural area, whereas, the *Juncus* zones of both areas were within 4.6 cm of

Table 1
Surveyed Elevations (centimeters above mean sea level) of the Major Nekton Sampling Sites in Both Zones of Natural and Constructed Areas (Each reference mark was surveyed by transet. All other elevations were determined relative to these marks)

Elevation Zone / Marsh Site	Reference Mark	Flume Weir	Lift Net	Difference
Spartina				
Natural	32.3	34.0	30.6	3.4
Constructed	7.3	17.4	14.2	3.2
Difference Between Marsh Sites		16.6	16.4	
Juncus				
Natural	39.9	39.9	39.7	0.2
Constructed				
Creek Mouth	35.3	38.0	35.7	2.3
Difference Between Marsh Sites		1.9	4.0	
Creek Head	33.5		33.5[1]	
Difference Between Marsh Sites			6.2	

[1] The lift net was placed with the reference mark at its center.

each other (as measured from the reference marks). The *Spartina* zone in the constructed area was, therefore, established at a substantially lower level than that of the natural marsh. This site was subsequently flooded more frequently and for longer durations than the natural *Spartina* zone. The greater range of elevations measured across the constructed area is a reflection of the sloped gradient across the site (as constructed). There was relatively little difference (0.2-3.4 cm) in elevation between the sites for flume weirs and lift nets in either zone of both areas, including the sites of the lift net at the mouth and head of the tidal creek.

Sediment texture was substantially different between the marsh areas (Table 2) reflecting the predominately sandy nature of the substrate of the constructed site. Sediments in the natural area were clayey-silt in the *Spartina* zone and silty-clay in the *Juncus* and high-marsh zones. All three textural components (sand, silt, and clay) were significantly different between sites for all three elevation zones. Within the natural marsh, sand was significantly lower in the *Juncus* zone than in either the low-marsh *Spartina* or high-marsh zone. In the constructed site, the sand component was significantly higher in the high-marsh zone, with concomitant significant low levels of silt. Clay content in this area was significantly different (low) near the creek head. The overall textural pattern within the natural marsh suggests that finer materials (silts and clays) are somewhat more prevalent in the high-marsh zones. In the constructed site, the pattern suggests that most fine materials are being

Table 2
Sediment Textural Composition (percent, (± SD)) in Three Elevational Zones of the Natural and Constructed Marsh Sites in January 1993 (Statistically significant differences are indicated for comparisons of each sediment component between marsh sites (horizontally across the table, asterisks not in parentheses) and between elevational zones within each marsh site (vertically within the table, asterisks in parentheses))

Elevational Zone Component	Natural Mean, SD	C-Mouth Mean, SD	C-Head Mean, SD
Spartina			
Sand	7.3 (5.1)***	86.5 (1.9)	86.0 (2.9)
Silt	51.6 (0.8)***	12.2 (1.3)	13.6 (2.8)
Clay	41.0 (5.0)***	1.2 (1.2)	0.3 (0.4)(*)
Juncus			
Sand	0.8 (0.9)***(*)	80.9 (2.3)	76.2 (9.0)
Silt	47.2 (5.6)**	14.5 (2.3)	22.5 (9.0)
Clay	51.9 (4.7)**	4.6 (2.1)	1.2 (0.3)
High Marsh			
Sand	5.0 (0.4)***	95.5 (3.6)(**)	92.9 (2.3)(*)
Silt	43.8 (4.7)***	0.6 (1.1)(***)	4.1 (3.6)(*)
Clay	51.1 (4.8)***	3.7 (2.5)	2.9 (1.9)

Note: * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$.

deposited in the lower zones (*Spartina* and *Juncus*) that are flooded more frequently. There was a distinct and somewhat flocculent layer (about 5 cm deep) of finer grained materials in the low-marsh *Spartina* zone, particularly at the mouth of the creek area of the constructed marsh, that appeared to have been deposited since construction. This layer was not present in adjacent barren areas in this zone.

Vegetation

The measured parameters of aboveground macrophytic vegetation in both zones of both marshes are summarized in Tables 3 and 4 for 1992 and 1993, respectively. Overall, the vegetative characteristics of both marshes were

Table 3
Summary of Plant Stand Measurements (means (± SD) per 0.25 m^2) in Both Zones of the Natural and Constructed Marsh Sites in October 1992 (To convert values to per square meter, multiply by 4)

Species	No. Stems		Live Biomass, g		Dead Biomass, g		Stem Height, cm	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con
***Spartina* Zone**								
Spartina alterniflora	59.2 (18.8)	55.4 (21.1)	150.3 (57.9)	166.7 (71.8)	54.8 (14.2)	44.2 (21.2)	87.0 (10.7)	107.7** (14.9)
Juncus roemerianus	1.3 (3.1)		1.0 (2.3)		0.1 (0.6)		98.0$^{n=2}$ (4.2)	
Distichlis spicata	1.0* (1.4)		0.3* (0.5)				36.5$^{n=4}$ (11.5)	
Total Vegetation	61.5 (18.8)	55.4 (21.1)	151.7 (57.9)	166.7 (71.8)	55.0 (14.0)	44.2 (21.2)		
***Juncus* Zone**								
Juncus roemerianus	191.2* (62.5)	140.7 (46.2)	168.4* (46.3)	115.6 (62.3)	164.9* (63.2)	106.1 (53.9)	137.2* (11.5)	120.1 (17.5)
Distichlis spicata	26.2 (39.0)	26.0 (30.8)	8.6 (12.4)	8.0 (10.4)	3.5 (3.6)	2.6 (4.4)	72.2$^{n=7}$ (8.9)	59.5$^{n=7}$ (11.0)
Spartina patens		5.7 (18.0)		2.5 (7.9)		1.0 (3.3)		67.0$^{n=1}$
Aster tenuifolius		0.1 (0.3)		0.03 (0.1)				43.0$^{n=1}$
Salicornia virginica		0.1 (0.3)		0.05 (0.1)				41.0$^{n=1}$
Total Vegetation	217.4 (69.4)	172.6 (58.3)	177.1* (55.1)	126.2 (56.8)	168.4* (63.4)	109.8 (52.0)		

Note: * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$.

Table 4
Summary of Plant Stand Measurements (means (± SD) per 0.25 m^2) in Both Zones of the Natural and Constructed Marsh Sites in August 1993 (To convert values to per square meter, multiply by 4)

	No. Stems		Live Biomass, g		Dead Biomass, g		Stem Height, cm	
Species	**Nat**	**Con**	**Nat**	**Con**	**Nat**	**Con**	**Nat**	**Con**
***Spartina* Zone**								
Spartina alterniflora	52.4 (11.2)	63.6 (28.9)	139.1 (39.5)	157.2 (90.3)	47.0 (20.8)	55.5 (36.5)	87.5 (7.9)	107.0** (17.1)
Juncus roemerianus	1.6 (3.3)	0.1 (0.3)	1.4 (3.3)	0.005 (0.01)	0.4 (1.4)		$75.2^{n=3}$ (57.7)	$9.9^{n=1}$
Distichlis spicata	4.8* (9.8)		1.6* (3.1)		0.5 (1.2)		$55.2^{n=4}$ (8.8)	
Total Vegetation	58.8 (8.9)	63.7 (28.9)	142.2 (38.3)	157.2 (90.3)	48.0 (20.3)	55.5 (36.5)		
***Juncus* Zone**								
Juncus roemerianus	124.5 (39.1)	113.8 (30.3)	126.5 (39.8)	101.0 (37.8)	156.2 (45.2)	124.3 (36.1)	138.8 (6.5)	131.5 (15.5)
Distichlis spicata	8.4 (6.9)	36.8* (26.7)	4.3^1 (3.2)	11.1 (8.2)	1.4 (2.1)	6.4** (4.3)	$65.8^{n=8}$ (19.7)	$71.8^{n=8}$ (7.5)
Spartina patens		3.4 (10.7)		1.5 (4.8)		1.3 (4.3)		$78.0^{n=1}$
Aster tenuifolius		0.3 (0.6)		0.002 (0.004)				$10.3^{n=1}$ (6.5)
Total Vegetation	132.9 (36.7)	154.3 (37.9)	130.8 (40.1)	113.6 (38.9)	157.6 (45.2)	132.1 (38.1)		

Note: * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$.
[1] $p = 0.07$.

similar in terms of the species present and their relative proportions. The *Spartina* zone of both marshes was dominated by *S. alterniflora*. Stem density of this species ranged from 96.2 to 89.1 percent in the natural marsh and from 99.8 to 100 percent in the constructed marsh in 1992 and 1993, respectively. Live biomass of *S. alterniflora* ranged from 97.8 to 99.0 percent in the natural marsh and from 99.9 to 100 percent in the constructed marsh in 1992 and 1993, respectively. The only parameters that were significantly different between marshes in this zone were the maximum measured height of *S. alterniflora* (higher in the constructed marsh) and the slightly but significantly greater density and live biomass of *Distichlis spicata* in the natural marsh in both years.

The *Juncus* zone of both marshes was dominated by *J. roemerianus*. Stem density of this species ranged from 87.9 to 93.6 percent in the natural marsh

and from 73.7 to 81.5 percent in the constructed marsh in 1992 and 1993, respectively. Live biomass of *J. roemerianus* ranged from 95.0 to 96.7 percent in the natural marsh and from 88.9 to 91.6 percent in the constructed marsh in 1992 and 1993, respectively. Values for stem density, live and dead biomass, and stem height of *J. roemerianus* were all significantly greater in the natural marsh in 1992, but not in 1993. Total vegetation live and dead biomass were also significantly higher in the natural marsh in 1992. *Distichlis spicata* was common in both marshes in both years, having greater stem height in the natural marsh in 1992 and being somewhat more prevalent in the constructed marsh in 1993 (significantly greater number of stems and dead biomass).

Belowground live root biomass values for both plant zones of both marshes are summarized in Table 5 for 1992 and 1993. Except for the *Juncus* zone in 1992, root mass was significantly greater in both zones of the natural marsh in both years. Root biomass was from 2.3 to 4.2 times greater in the *Spartina* zone and from 1.3 to 1.9 times as great in the *Juncus* zone of the natural marsh. Belowground biomass was similar across the length of the constructed marsh.

Table 5
Belowground Live Root Biomass Values (means (± SD) per 75.4 cm^2) in the *Spartina* and *Juncus* Zones of the Natural and Constructed Marsh Sites in November 1992 and March 1993 (To convert values to per square meter, multiply by 132.6)

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Date Marsh Zone	Mean	SD	Mean	SD	Mean	SD	Mean	SD
November 1992								
Spartina Zone***	17.2^A	(3.1)	5.3^B	(1.2)	7.0^B	(2.4)	7.3^B	(2.2)
Juncus Zone	18.9	(5.5)	12.6	(2.7)	13.6	(5.1)	13.5	(1.2)
March 1993								
Spartina Zone**	13.7^A	(4.0)	4.2^B	(1.6)	3.2^B	(0.7)	4.8^B	(1.9)
Juncus Zone**	19.1^A	(3.8)	10.8^B	(2.5)	11.9^B	(2.8)	9.8^B	(1.6)

Note: ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; Values with common superscript letters are not different from each other.

Benthic Macroinfauna (Core Samples)

A total of 32 taxa of macroinfauna were identified from core samples from both marshes (Table 6): 27 species were recorded from the *Spartina* zone, 30 species from the *Juncus* zone. There were somewhat more taxa in both zones of the constructed marsh compared with the natural marsh. Similarity between these assemblages was, however, relatively high (C > 0.60).

Table 6

Taxonomic List and Occurrence (Numerals indicate the number of samples in which taxa occurred out of three samples collected) of Small Benthic Organisms in the *Spartina* and *Juncus* Zones of the Natural and Constructed Marsh Sites

Major Taxonomic Group Species	*Spartina* Zone		*Juncus* Zone	
	Natural	Constructed	Natural	Constructed
Oligochaeta				
Monopylephorus parvus Ditlevsen	2		2	
Monopylephorus rubroniveus Levinsen	1	1	2	2
Monopylephorus sp.	2	1	2	1
Paranais grandis (Harmon)	1	1	2	1
Enchytraeid sp.	2	1	2	3
Polychaeta				
Neanthes succinea (Frey & Leuckart)	3	3	1	3
Laeonereis culveri (Webster)		2		1
Namalycastis abiuma (Muller)	2	2	2	1
Capitella cf. *capitata* (Fabricius)	3	3	3	3
Hobsonia florida (Hartman)		1		
Streblospio benedicti Webster	1	1	1	1
Gastropoda				
Hydrobiid sp.		1		2
Pelecypoda				
Polymesoda caroliniana (Bosc)[1]	2		2	2
Geukensia demissa (Dillwyn)[1]	3	3	2	3
Crustacea				
Hargeria rapax (Harger)	2	3	2	3
Munna reynoldsi Frankenberg & Menzies			1	
Cassidinidea ovalis (Say)		1	1	
Corophium louisianum Shoemaker		2		2
Gammarus sp.	1	1		2
Melita sp.	2	1	2	1
Orchestia sp.	2	1		2
Insecta				
Culicoides sp.	3	1	3	3
Bezzia sp.			2	1
Chironomid sp. A	1	2	2	3
Chironomid sp. B		1		
Pelastoneurus sp.		1		2
Thinophilus sp.	1	2	2	3
Dimecoenia sp.		1		2
Notiphila sp.				1
Ephydrid sp.		1		1
Tabanus sp.				1
Chrysops sp.			1	
Total Number of Species	18	25	20	26
Similarity (C)	0.74		0.69	

[1] Only small individuals (≤2 cm) of this taxa were included as part of these samples.

Overall, the assemblages of both zones included 5 taxa of oligochaetes, 6 species of polychaetes, 3 taxa of mollusc (gastropods and pelecypods), 7 taxa of crustaceans, and 11 taxa of insects (immature stages). Two of these taxa were found only in the *Spartina* zone (the polychaete *Hobsonia florida* and the insect chironomid species B) and five taxa only in the *Juncus* zone (the crustacean isopod *Munna reynoldsi* and the insects *Bezzia* sp., *Notiphila* sp., *Tabanus* sp., and *Chrysops* sp.). Three taxa were found only in the natural marsh (the oligochaete *Monpylephorus parvus*, the isopod *Munna reynoldsi*, and the insect *Chrysops* sp.), and 10 taxa were found only in the constructed marsh (the polychaetes *Laeonereis culveri* and *Hobsonia florida*, the hydrobiid sail, the amphipod *Corophium louisianum*, and the insects chironomid sp. B, *Pelastoneurus* sp., *Dimecoenia* sp., *Notiphila* sp., ephydrid sp., and *Tabanus* sp.). Both assemblages were most diverse (i.e., in terms of numbers of taxa) in the fall: 23 taxa in the *Spartina* zone and 25 taxa in the *Juncus* zone. Fifteen taxa occurred in the *Spartina* zone in both spring and summer, while 19 taxa were recorded in the *Juncus* zone during the same periods. Seasonal patterns of assemblage characteristics (taxonomic richness, equitability, dominant organisms, and relative abundance) for each zone are discussed below. Assemblages from each of the three transects in the constructed marsh (mouth of creek, middle creek, head of creek) and the single transect in the natural marsh were compared and are discussed below as separate groups.

Spartina zone assemblages

The fall *Spartina* zone assemblage (Table 7) had the greatest overall taxonomic richness in each of the four sites sampled compared with spring (Table 8) and summer samples (Table 9). Equitability in the fall was also relatively high (1-d > 0.60) and similar between all sites and between marshes. The tanaeid crustacean *Hargeria rapax* was the dominant organism in three of the four sites (27.0 percent in the natural marsh, 34.6 and 25.2 percent in the mouth of creek and head of creek sites of the constructed marsh, respectively), as well as being a subdominate organism in the middle creek site (21.8 percent). The oligochaete *Monopylephorus* sp. was the dominate organism in the middle creek site within the constructed marsh and was a subdominant in the remaining three sites. Overall, the assemblages of the constructed sites were dominated by a somewhat different suite, but similar number of taxa compared with the natural marsh. Similarity values between the natural marsh and constructed sites were somewhat lower than those between constructed sites, but similarity among all four assemblages was relatively high (C > 0.50) overall. Total organism density was significantly greater (3.5 to 5.8 times) in all three constructed sites compared with the natural marsh, as were the densities of the following organisms: *Monophylephorus rubroniveus*, *Monophylephorus* sp., *Laenonereis culveri* (two sites), *Hargeria rapax*, and *Corophium louisianum*. *Neanthes succinia* was significantly more abundant in the mouth site of the constructed site compared with other sites, and *Capitella capitata* was more abundant in the mouth and head sites of the constructed marsh.

Table 7

Densities (means ($\pm$ SD) per 75.4 cm^2) of Small[1] Benthic Organisms in the *Spartina* Zones of the Natural and Constructed Marsh Sites in November 1992 (To convert values to per square meter, multiply by 132.6. Bolded values signify common organisms in each sample ($\geq$5 percent of total density))

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Monopylephorus parvus	**0.6**	(1.3)						
*Monopylephorus rubroniveus**	^{B}		**12.2^{A}**	(17.5)	**5.6^{A}**	(4.5)	**10.4^{A}**	(10.0)
Monopylephorus sp.*	**1.0^{B}**	(2.2)	**4.8^{A}**	(3.4)	**11.0^{A}**	(9.6)	**5.4^{A}**	(3.5)
Paranais grandis			0.4	(0.8)	0.2	(0.4)	0.2	(0.4)
Enchytraeid sp.	0.2	(0.4)					1.2	(1.6)
*Neanthes succinea**	0.4^{A}	(0.5)	1.4^{B}	(0.5)	0.8^{A}	(0.8)	0.2^{A}	(0.4)
*Laeonereis culveri**	^{B}		**9.0^{A}**	(7.7)	0.4^{B}	(0.5)	**4.2^{A}**	(1.9)
Namalycastis abiuma	0.2	(0.4)	0.2	(0.4)	(0.2)	(0.4)	0.8	(0.8)
*Capitella capitata***	**0.8^{B}**	(1.3)	**5.4^{A}**	(2.5)	**3.0^{B}**	(2.0)	**11.6^{A}**	(7.7)
Hobsonia florida			0.2	(0.4)				
Streblospio benedicti	0.2	(0.4)			0.2	(0.4)	0.2	(0.4)
Polymesoda caroliniana[1]	0.2	(0.4)						
Geukensia demissa[1]	**1.4**	(2.0)			0.4	(0.5)	1.4	(1.5)
*Hargeria rapax***	**2.6^{B}**	(4.7)	**19.4^{A}**	(13.5)	**7.4^{A}**	(3.2)	**13.2^{A}**	(9.1)
Cassidinidea ovalis			0.2	(0.4)				
*Corophium louisianum**	^{B}		2.4^{A}	(2.7)	**2.2^{A}**	(0.8)	1.0^{A}	(1.2)
Gammarus sp.	**0.6**	(0.8)						
Melita sp.	**0.8**	(1.3)						
Orchestia sp.	0.2	(0.4)						
Culicoides sp.	0.2	(0.4)						
Chironomid sp. A	0.2	(0.4)	0.4	(0.8)	**2.2**	(2.6)	2.0	(2.3)
Pelastoneurus sp.					0.2	(0.4)	0.2	(0.4)
Thinophilus sp.							0.2	(0.4)
Total Organisms**	9.6^{B}	(8.5)	56.0^{A}	(14.1)	33.8^{B}	(13.9)	52.2^{A}	(23.2)
Species Richness	15		12		13		15	
Species Equitability (1-d)	0.72		0.65		0.67		0.74	
Similarity (C)			Cons-A		Cons-B		Cons-C	
	Natural		0.44		0.57		0.60	
	Cons-A				0.80		0.74	
	Cons-B						0.92	

Note: * = Statistically significant at $p \leq 0.05$; ** = Statistically significant at $p \leq 0.01 > 0.001$; Values with common superscript letters are not different from each other.

[1] Only small individuals ($\leq$2 cm) of this taxa were included as part of these samples.

Table 8
Densities (means (± SD) per 75.4 cm²) of Small[1] Benthic Organisms in the *Spartina* Zones of the Natural and Constructed Marsh Sites in March 1993 (To convert values to per square meter, multiply by 132.6. Bolded values signify common organisms in each sample (≥5 percent of total density))

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Neanthes succinea	0.2	(0.4)	0.6	(0.5)	0.2	(0.4)	1.0	(0.7)
Laeonereis culveri			0.2	(0.4)				
Namalycastis abiuma					0.2	(0.4)		
Capitella capitata	0.4	(0.8)	1.0	(1.7)	1.2	(1.0)	1.2	(1.0)
Hydrobiid sp.					0.2	(0.4)		
Geukensia demissa[1]	**2.2**	(4.3)			0.6	(0.5)	0.6	(0.8)
Hargeria rapax	**14.6**	(11.1)	**34.2**	(42.0)	**29.2**	(26.3)	**54.8**	(36.9)
Corophium louisianum			0.8	(1.0)	1.0	(1.7)	0.6	(1.3)
Gammarus sp.			0.2	(0.4)				
Melita sp.	0.2	(0.4)			0.2	(0.4)		
Orchestia sp.							0.2	(0.4)
Culicoides sp.**	**1.8**[A]	(0.8)	[B]		[B]		0.4[B]	(0.5)
Chironomid sp. A			**3.0**	(2.8)	**2.6**	(2.7)	**3.6**	(4.3)
Chironomid sp. B					0.6	(0.8)		
Thinophilus sp.	0.2	(0.4)	0.2	(0.4)			0.2	(0.4)
Total Organisms	19.6	(9.2)	40.2	(47.7)	36.0	(29.8)	62.6	(36.9)
Species Richness	7		8		10		9	
Species Equitability (1-d)	0.25		0.14		0.18		0.12	
Similarity (C)			Cons-A		Cons-B		Cons-C	
	Natural		0.53		0.58		0.75	
	Cons-A				0.55		0.70	
	Cons-B						0.63	

Note: * = Statistically significant at p ≤ 0.05; ** = Statistically significant at p ≤ 0.01 > 0.001; Values with common superscript letters are not different from each other.
[1] Only small individuals (≤2 cm) of this taxa were included as part of these samples.

Taxonomic richness of the spring *Spartina* zone assemblage (Table 8) was from 23 to 53 percent lower than that of the fall sample. Equitability was also considerably lower (1-d ≤ 0.25) than that of the fall sample, but relatively equal between all sites in the constructed marsh and slightly higher in the natural marsh. *Hargeria rapax* dominated all four sites in the spring, representing 74.4 percent of the natural marsh assemblage and from 81.1 percent (middle creek) to 87.5 percent (head of creek) of the constructed marsh

Table 9
Densities (means (± SD) per 75.4 cm^2) of Small[1] Benthic Organisms in the *Spartina* Zones of the Natural and Constructed Marsh Sites in August 1993 (To convert values to per square meter, multiply by 132.6. Bolded values signify common organisms in each sample (≥5 percent of total density))

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
*Monopylephorus parvus***	**2.6**	(2.7)						
Monopylephorus rubroniveus		0.2	(0.4)					
Monopylephorus sp.**	**5.2**	(3.9)						
Paranais grandis	0.4	(0.5)						
Enchytraeid sp.**	**1.6**	(1.6)						
Neanthes succinea	0.2	(0.4)	**0.6**	(0.8)	**0.2**	(0.4)		
*Namalycastis abiuma***	**1.2**	(0.8)						
*Capitella capitata***	**1.8^{B}**	(0.8)	**0.2^{A}**	(0.4)	**0.6^{A}**	(0.8)	**0.2^{A}**	(0.4)
Polymesoda caroliniana[1]	0.2	(0.4)						
Geukensia demissa[1]	0.6	(0.8)					**0.2**	(0.4)
Hargeria rapax			**0.2**	(0.4)	**1.2**	(1.7)	**0.4**	(0.8)
Orchestia sp.	0.2	(0.4)						
Culicoides sp.	0.2	(0.4)						
Dimecoenia sp.							**0.2**	(0.4)
Ephydrid sp.							**0.2**	(0.4)
Total Organisms	14.4^{B}	(9.4)	1.0^{A}	(1.0)	2.0^{A}	(1.4)	1.2^{A}	(2.1)
Species Richness	12		3		3		5	
Species Equitability (1-d)	0.63		0.40		0.40		0.66	
Similarity (C)			Cons-A		Cons-B		Cons-C	
	Natural		0.13		0.13		0.11	
	Cons-A				1.00		0.50	
	Cons-B						0.50	

Note: * = Statistically significant at $p \leq 0.05$; ** = Statistically significant at $p \leq 0.01 > 0.001$; Values with common superscript letters are not different from each other.
[1] Only small individuals (≤2 cm) of this taxa were included as part of these samples.

assemblages. Overall, both marshes were dominated by an equal number but different suite of taxa. Similarity values were somewhat more comparable between natural and constructed sites and were again relatively high ($C > 0.50$): the highest similarity was between the natural site and the head of creek site of the constructed marsh. Total organism density was again greater (1.8 to 3.1 times) overall in the constructed sites but not significantly different from the natural marsh. *Culicoides* sp. was the only organism having significantly greater density in any given site (highest in the natural marsh).

The summer *Spartina* zone assemblage (Table 9) had the lowest overall taxonomic richness for this zone, particularly for constructed marsh sites (23 to 33 percent lower than fall levels). The natural marsh assemblage richness (S = 12) was nearly comparable with that of the fall assemblage (S = 15). Equitability in this period was nearly that of the fall sample (1-d = 0.40 - 0.66) due in part to the effect of lower taxonomic richness. *Hargeria rapax* again was the dominant organism in two sites (60.0 and 33.3 percent of the middle creek and head of creek sites of the constructed marsh). *Monopylephorus* sp. dominated the natural marsh site, while *Neanthes succinea* was dominant in the mouth of the creek site of the constructed marsh. Unlike in previous seasons, the natural marsh supported a larger number, but a different suite of taxa compared with constructed marsh sites. Similarity values were extremely low (C > 0.15) between natural and constructed sites, but relatively high between constructed sites (C = 0.50 - 1.0), again due to the affect of low taxonomic richness. Unlike in previous seasons, total organism density was significantly greater (7.2 to 14.0 times) in the natural marsh compared with constructed sites, as were the densities of the following organisms: *M. parvus*, *Monopylephorus* sp., enchytraeid sp., *N. abiuma*, and *C. capitata*. Total densities were, however, the lowest overall among the three seasons sampled (except for the natural marsh, which was lowest in fall).

In summary, the *Spartina* zone macroinfaunal assemblages of both marshes had comparable taxonomic richness in fall and spring, with minimal richness in summer. Equitability was comparable among sites in any given season: relatively high in fall and summer, low in spring. *Hargeria rapax* was the dominant organisms overall. All assemblages consisted of similar suites and numbers of taxa in two of three seasons (fall and spring). Similarity between sites was high (C > 0.50) overall in fall and spring, but low in summer, with values being somewhat greater between constructed sites. Total density was greater in constructed marsh sites in two of three seasons (fall and spring) and greater in the natural marsh in summer. More taxa showed greater densities in constructed marsh sites in fall and more taxa with greater densities in natural marsh in summer.

Juncus zone assemblages

As in the *Spartina* zone, the fall *Juncus* zone assemblage (Table 10) had the greatest taxonomic richness in all four sites compared with spring (Table 11) and summer samples (Table 12). Equitability was highest for the natural marsh compared with constructed sites (1.4 to 3.1 times). Also like the fall *Spartina* zone assemblages, *H. rapax* was the dominant organisms in three of the four sites (83.0 percent in the creek mouth, 64.8 percent in the middle creek, and 76.3 percent in the head of the creek sites of the constructed marsh). The oligochaete *Paranais grandis* was the dominant organism in the natural marsh. The assemblage of the natural marsh was dominated by a different suite and larger number of taxa compared with constructed marsh sites, which were dominated largely by *H. rapax*. Similarity between sites was essentially equal among constructed sites (C = 0.56 - 0.57) and

Table 10
Densities (means (± SD) per 75.4 cm^2) of Small[1] Benthic Organisms in the *Juncus* Zones of the Natural and Constructed Marsh Sites in November 1992 (To convert values to per square meter, multiply by 132.6. Bolded values signify common organisms in each sample (≥5 percent of total density))

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Monopylephorus parvus	0.6	(1.3)						
Monopylephorus rubroniveus	**3.6**	(3.9)			**1.2**	(2.6)		
Monopylephorus sp.	**3.4**	(6.5)			0.2	(0.4)	0.2	(0.4)
Paranais grandis	**17.6**	(35.5)			0.2	0.4		
Enchytraeid sp.	0.8	(1.3)					0.4	(0.8)
Neanthes succinea			0.6	(0.5)	0.4	(0.8)		
Namalycastis abiuma	**1.6**	(2.6)						
Capitella capitata	**2.4**	(2.6)	0.2	(0.4)	**2.0**	(3.9)	0.6	(0.8)
Streblospio benedicti	0.4	(0.8)			0.6	(1.3)		
Hydrobiid sp.			0.4	(0.8)			0.2	(0.4)
Polymesoda caroliniana[1]	0.2	(0.4)	0.2	(0.4)	0.4	(0.8)	0.6	(1.3)
Geukensia demissa[1]	0.2	(0.4)	1.0	(1.7)	**1.2**	(1.3)	0.6	(0.8)
Hargeria rapax	1.2	(1.7)	**19.6**	(12.5)	**14.0**	(18.5)	**14.2**	(16.9)
Munna reynoldsi	0.2	(0.4)						
Cassidinidea ovalis	0.2	(0.4)						
*Corophium louisianum**	^{B}		0.4^{A}	(0.8)	0.6^{A}	(0.8)	^{B}	
Gammarus sp.	0.8	(1.7)	0.2	(0.4)				
Melita sp.	**1.8**	(2.1)			0.2	(0.4)	0.2	(0.4)
Orchestia sp.					0.2	(0.4)	0.2	(0.4)
Culicoides sp.	0.4	(0.8)					0.2	(0.4)
Bezzia sp.	0.2	(0.4)					0.2	(0.4)
Chironomid sp. A					0.2	(0.4)	0.2	(0.4)
Pelasoneurus sp.			0.4	(0.5)			0.4	(0.5)
Thinophilus sp.			0.4	(0.8)	0.2	(0.4)		
Dimecoenia sp.			0.2	(0.4)			0.4	(0.5)
Total Organisms	35.6	(54.2)	23.6	(11.6)	21.6	(26.9)	18.6	(17.6)
Species Richness	17		11		14		14	
Species Equitability (1-d)	0.50		0.16		0.35		0.23	
Similarity (C)			Cons-A		Cons-B		Cons-C	
	Natural		0.35		0.58		0.72	
	Cons-A				0.56		0.56	
	Cons-B						0.57	

Note: * = Statistically significant at $p \leq 0.05$; Values with common superscript letters are not different from each other.
[1] Only small individuals (≤2 cm) of this taxa were included as part of these samples.

Table 11
Densities (means (± SD) per 75.4 cm^2) of Small[1] Benthic Organisms in the *Juncus* Zones of the Natural and Constructed Marsh Sites in March 1993 (To convert values to per square meter, multiply by 132.6. Bolded values signify common organisms in each sample (≥5 percent of total density))

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Monopylephorus rubroniveus						0.2	(0.4)	
Enchytraeid sp.					0.2	(0.4)		
Neanthes succinea	**0.6**	(0.5)	0.2	(0.4)			0.4	(0.5)
Capitella capitata	**2.6**	(2.0)	1.6	(2.5)	0.6	(0.8)	0.8	(0.4)
Hydrobiid sp.			0.2	(0.4)	0.8	(1.3)	1.0	(1.7)
Polymesoda caroliniana[1]			0.2	(0.4)				
*Geukensia demissa**[1]	^{B}		**2.6**	(2.4)	1.6^{A}	(1.5)	0.6^{A}	(0.8)
*Hargeria rapax***	**0.6^{B}**	(0.5)	**46.6^{A}**	(51.7)	**54.4^{A}**	(55.5)	**39.8^{A}**	(37.5)
Corophium louisianum							0.2	(0.4)
Gammarus sp.							0.2	(0.4)
Melita sp.	**0.4**	(0.8)						
Orchestia sp.					0.2	(0.4)		
Culicoides sp.	**0.8**	(0.8)			0.2	(0.4)	0.6	(1.3)
Bezzia sp.	**0.4**	(0.5)						
Chironomid sp. A	0.2	(0.4)					**2.6**	(4.3)
Pelasoneurus sp.			0.2	(0.4)	0.6	(0.8)	0.2	(0.4)
Thinophilus sp.	0.2	(0.4)	0.2	(0.4)	0.4	(0.5)		
Notiphila sp.					0.2	(0.4)	0.6	(0.8)
Tabanus sp.							0.2	(0.4)
Total Organisms*	5.8^{B}	(1.6)	51.8^{A}	(52.7)	59.4^{A}	(57.2)	47.2^{A}	(43.5)
Species Richness	8		8		11		12	
Species Equitability (1-d)	0.55		0.10		0.08		0.15	
Similarity (C)			Cons-A		Cons-B		Cons-C	
	Natural		0.50		0.42		0.50	
	Cons-A				0.63		0.60	
	Cons-B						0.60	

Note: * = Statistically significant at $p \leq 0.05$; ** = Statistically significant at $p \leq 0.01 > 0.001$; Values with common superscript letters are not different from each other.
[1] Only small individuals (≤2 cm) of this taxa were included as part of these samples.

Table 12
Densities (means (± SD) per 75.4 cm^2) of Small[1] Benthic Organisms in the *Juncus* Zones of the Natural and Constructed Marsh Sites in August 1993 (To convert values to per square meter, multiply by 132.6. Bolded values signify common organisms in each sample (≥5 percent of total density))

	Sample Sites							
	Natural		Cons-A		Cons-B		Cons-C	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Monopylephorus parva	0.4	(0.5)						
*Monopylephorus rubroniveus**	**1.8**	(2.9)						
Monopylephorus sp.**	**2.0**	(2.0)						
*Paranais grandis***	**2.8**	(3.2)						
Enchytraeid sp.	**1.0**	(1.2)	**0.2**	(0.4)	**10.8**	(18.1)	**2.0**	(3.3)
Neanthes succinea			**0.2**	(0.4)				
Laenonereis culveri					0.2	(0.4)	0.2	(0.4)
Namalycastis abiuma	0.8	(0.8)			0.2	(0.4)	0.4	(0.8)
*Capitella capitata***	**3.8**^{B}	(1.6)	**0.4**^{B}	(0.5)	^{A}		**0.8**^{A}	(0.8)
Polymesoda caroliniana[1]	**1.0**	(1.0)						
Geukensia demissa[1]	0.6	(0.5)	**0.6**	(0.8)	0.6	(0.8)	**0.6**	(0.5)
Hargeria rapax			**0.6**	(0.8)	0.6	(0.8)	**2.6**	(3.9)
Melita sp.	0.2	(0.4)						
Culicoides sp.	**1.0**	(1.2)			0.4	(0.5)	0.2	(0.4)
Chironomid sp. A	0.2	(0.4)					0.2	(0.4)
Thinophilus sp.	0.6	(0.5)	**0.8**	(0.8)	0.4	(0.8)	**0.8**	(0.8)
Dimecoenia sp.					0.4	(0.8)	**0.6**	(1.3)
Chrysops sp.	0.2	(0.4)						
Ephydrid sp.					0.4	(0.8)		
Total Organisms	16.4	(9.6)	2.8	(1.3)	14.0	(19.8)	8.4	(4.8)
Species Richness	14		6		9		10	
Species Equitability (1-d)	0.76		0.71		0.22		0.69	
Similarity (C)			Cons-A		Cons-B		Cons-C	
	Natural		0.40		0.43		0.58	
	Cons-A				0.53		0.62	
	Cons-B						0.84	

Note: * = Statistically significant at $p \leq 0.05$; ** = Statistically significant at $p \leq 0.01 > 0.001$; Values with common superscript letters are not different from each other.
[1] Only small individuals (≤2 cm) of this taxa were included as part of these samples.

comparable (C = 0.58, middle creek) and higher (C = 0.72, head of creek) between two of these sites and the natural marsh. Total organism density was only slightly higher (1.5 to 1.9 times) in the natural marsh, but not significantly different among sites. *Corophium louisianum* was the only organism found to be significantly more abundant in any sites (mouth of creek and middle creek sites of the constructed marsh).

Taxonomic richness of the spring *Juncus* assemblage (Table 11) was substantially lower in the natural marsh (52.9 percent) but only somewhat lower in the constructed sites compared with the fall sample (14.2 to 27.2 percent). Equitability showed a similar pattern among sites in this season, as in the fall, with a relatively high value for the natural marsh (1-d = 0.50) and lower (3.6 to 6.8 times) but equal values among constructed sites. *Hargeria rapax* continued to dominate all three constructed marsh sites (89.9 percent in the mouth of the creek, 91.5 percent in the middle creek, and 84.3 percent in the head of the creek sites). *Capitella capitata* dominated the natural marsh assemblage (44.8 percent). Although six taxa were numerically dominant in the natural marsh, given the low density values by which percentage values are based, it is reasonable to conclude that all four sites were dominated largely by a single taxa (*C. capitata* in the natural marsh, *H. rapax* in all three constructed marsh sites). Similarity between sites was again essentially equal among constructed sites (C = 0.60-0.63), but somewhat lower between the natural marsh and constructed sites (C = 0.42-0.50). Total organism density was significantly greater (8.1 to 10.2 times) in all three constructed sites compared with the natural marsh, as were the densities of *G. demissa* and *H. rapax*.

The summer *Juncus* zone assemblages (Table 12) had the lowest overall taxonomic richness for this zone, particularly for constructed marsh sites (28 to 45 percent lower than fall sample levels). The natural marsh assemblage richness (S = 14) was nearly that of the fall assemblage (S = 17). Equitability was relatively high (1-d > 0.65) for the natural marsh and two of the constructed marsh assemblages. The middle creek marsh site had a relatively low value for equitability (1-d = 0.22). A different taxa dominated each of the four sites: *C. capitata* in the natural marsh (23.1 percent), and the insect *Thinophilus* sp. in the mouth of creek (28.5 percent), enchytraeid sp. (77.1 percent) in the middle creek, and *H. rapax* (30.9 percent) in the head of the creek sites of the constructed marsh. The assemblages of two of the constructed sites (mouth and head of the creek) were dominated by the same general suite and number of taxa compared with the natural marsh, which has a similar number but different suite of dominant taxa. Similarity was somewhat greater between constructed sites (C = 0.53-0.84) compared with that of natural and constructed sites (C = 0.40-0.58). Total organism density, while not significantly different among sites, was highest in the natural marsh (1.9 to 5.8 times) and the middle creek site (1.6 to 5.0 times) of the constructed marsh. As in the *Spartina* zone, these values represented the lowest overall densities for all three seasons (except for the natural zone, lowest in spring). Four taxa were found at significantly higher densities in the natural marsh, including *M. rubroniveus*, *Monopylephorus* sp. *P. grandis*, and *C. capitata*.

In summary, the *Juncus* zone macroinfaunal assemblages of both marshes had comparable taxonomic richness in fall and spring, with minimal richness in the summer for constructed sites and in the spring for the natural marsh. Equitability was relatively low, but generally comparable in constructed sites in fall and spring compared with higher and more moderate equitability in the natural marsh. Equitability was relatively high and more comparable in summer across all four sites. *Hargeris rapax* dominated constructed sites in fall and spring, with minimal occurrence in the natural marsh. Natural marsh assemblages consisted of different suites and greater numbers of taxa in two of three seasons (fall and spring) compared with sites in the constructed marsh. Similarity between sites was high ($C \geq 0.50$) in all seasons, but somewhat greater between constructed sites. Total density was greater in constructed marsh sites in spring and comparable among all sites in fall and summer. More taxa showed greater densities in constructed sites in spring, and more taxa with greater densities occurred in the natural marsh during summer.

Benthic Macroinfauna (Hand Samples)

Eight large macrofaunal taxa were encountered in hand samples (six in each elevational zone) from both marshes (Table 13). Four of the eight taxa were common to both zones (*Geukensia demissa*, *Littorina irrorata*, *Neritina usnea*, and *Uca*); three of these also occurred in both marshes. Four taxa were collected only in the constructed marsh (*Crassostrea virginica*, *Cerithidea pliculosa*, *Polymesoda caroliniana*, and *N. usnea*), while one taxa was found only in the natural marsh (*Melampus bidentatus*). Of those taxa collected in only one marsh or zone, all but two (*C. virginica* and *C. pliculosa*) were observed to be present in the other marsh or zone, but simply were not encountered in samples. *Neritina usnea* and *P. caroliniana*, for example, while absent from samples, were both observed in the natural *Juncus* marsh, but because of their relatively low densities, were not collected. *Melampus bidentatus* was similarly present in the constructed marsh, but at very low numbers. *Cerithidea pliculosa* and *C. virginica*, on the other hand, occurred only in the low *Spartina* zone of the constructed marsh, likely a function of the near-subtidal condition of this zone (i.e., lower than normal elevation), which is the preferred habitat for these species. Cursory observations and collections of dead shell of *P. carolinana* within both marshes were also made over the course of sampling and indicated a similarity in the upper range in size of shells of this species. Shells as large as 2.5-3.0 cm in width were commonly observed in the constructed *Juncus* zone and are within the range of size of individuals that would have colonized the site soon after construction.

Three taxa were common across both zones and marsh sites, but showed some differences in abundance between marshes. *Geukensia demissa* occurred at significantly greater density in the *Spartina* zone of the natural marsh and in the mouth of the creek portion of the *Juncus* zone in the constructed marsh. *Littorina irrorata* was found at significantly greater densities in both zones of

Table 13
Densities (means (± SD) per m²) of Large[1] Benthic Organisms in the *Spartina* and *Juncus* Zones of the Natural and Constructed Marsh Sites in November 1992

Zone/Species	Natural Mean	Natural SD	Cons-A Mean	Cons-A SD	Cons-B Mean	Cons-B SD	Cons-C Mean	Cons-C SD
***Spartina* Zone**								
*Geukensia demissa****	36.4^{A}	(18.2)	^{B}		0.8^{B}	(1.3)	3.4^{B}	(7.0)
Crassostrea virginica					0.6	(0.8)		
*Littorina irrorata**	79.8^{A}	(39.8)	18.4^{B}	(11.0)	20.2^{B}	(18.3)	17.0^{B}	(6.7)
Neritina usnea	0.4	(0.5)	1.2	(1.0)			1.2	(1.3)
Cerithidea pliculosa					1.2	(1.6)	1.8	(2.1)
Uca burrows***	31.0^{A}	(8.2)	0.6^{B}	(0.8)	2.8^{B}	(2.9)	6.0^{B}	(4.4)
***Juncus* Zone**								
*Geukensia demissa**	6.2^{B}	(6.0)	18.6^{A}	(11.8)	2.6^{B}	(2.7)	5.6^{B}	(4.6)
Polymesoda caroliniana			0.2	(0.4)				
*Littorina irrorata**	12.0^{A}	(6.9)	21.4^{B}	(22.0)	6.0^{B}	(5.7)	1.0^{B}	(1.0)
*Neritina usnea**	^{A}		1.2^{B}	(1.0)	^{A}		1.0^{B}	(1.4)
*Melampus bidentatus****	1.0	(0.7)						
Uca burrows	17.6	(4.6)	8.8	(6.7)	12.0	(11.7)	15.2	(3.9)

Note: * = Statistically significant at $p \leq 0.05$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p < 0.001$. Values with common superscript letters are not different from each other.
[1] Individuals typically >1-2 cm and detectable with the naked eye or by touch.

the natural marsh, while *Uca* burrows (assumed to be *Uca longisignalis* Salmon and Atsaides) and *M. bidentatus* were found in significantly greater numbers in the *Spartina* and *Juncus* zones of the natural marsh, respectively. In summary, the natural marsh supported greater numbers of *Littorina* overall, and *Geukensia* and *Uca* in selected zones. Some portions of the constructed marsh supported greater numbers of *Geukensia* and *Neritina*, and although not reflected in sample statistics, a healthy population of *P. caroliniana*.

Nekton (Fish and Shellfish)

Flume weir samples

As previously noted, each replicate flume weir sample was set to consist of the combined collections of nekton sampled over a 2-day period (i.e., two

high tide events) and that two such replicates would be collected over the 4- to 5-day period of spring high tides during each sampling event. Tidal conditions are, however, often affected by meteorological conditions along the northern Gulf of Mexico coast. In winter, strong northerly winds can prevent anticipated high water from flooding the marsh. Alternately, strong southerly winds in the warmer portions of the year can maintain high-water conditions for extended periods. Because of these occurrences throughout the course of this study, adjustments to what is defined above as a replicate sample were made to allow statistical comparisons of samples across flume weir sites. The most common of these situations involved the loss of the 2nd-day portion of a replicate sample due to either the lack of a flooding event (north winds) or the maintenance of a flood event on the 2nd day that prevented the recovery of that portion of the replicate sample. In some cases, complete samples (both days) were obtained for some flume weirs, but not for others. In these cases, statistical comparisons were made of first-day samples alone across sites. In other cases, a prolonged tide may have prevented the collection of the first-day sample, forcing its collection on what was the 2nd day. In this case, the sample collected on the 2nd day was assumed to be and treated as a "first-day" sample.

The November 1992 samples from both marshes consisted of 1-day samples (single-tide), in part because of the preliminary nature of this sample. Other first-day samples included *Spartina* zone samples for March and April 1993 and April and May 1994 and *Juncus* zone samples in May 1993 and April 1994. Tidal flooding problems also led to the lack of a 2nd replicate sample in the constructed marsh *Spartina* zone in March 1993 and the constructed marsh *Juncus* zone in September 1993; statistical comparison was not possible for these two cases.

A total of 23 species of fish (14 families) and four species of shellfish (shrimps and crabs) were identified from both marshes (Table 14): 21 species of fish and 4 species of shellfish from the *Spartina* zone and 17 species of fish and 4 species of shellfish from the *Juncus* zone. The number of taxa collected from both zones of both marshes were similar overall, reflected by the high values for similarity ($C > 80$). All four species of shellfish were common to both marshes, while six species of fish were unique to the *Spartina* zone (*Micropogon undulatus*, *Cynoscion nebulosus*, *Caranx hippos*, *Anchoa mitchelli*, *Synodus foetens*, and *Arius felis*) and two species to the *Juncus* zone (*Lucania parvus* and *Dormitator maculatus*). Killifishes dominated both marsh zones during most seasons except in spring (April-May) when the juveniles of several estuarine-dependent marine species (i.e., estuarine transients) were present.

The *Spartina* zone nekton assemblages of both the natural and constructed marshes (Table 15) were similar in terms of species richness overall (22 species in the natural marsh, 24 species in the constructed marsh) and across all seven sampling events. Richness was highest in the spring (May 1993 and 1994) and fall (September 1994), in large part because of the seasonal occurrence of estuarine transient species (e.g., brown shrimp and spot in spring,

Table 14
Taxonomic List and Occurrence of Nektonic Organisms Collected in the *Spartina* and *Juncus* Zones of the Natural and Constructed Marsh Sites Over Seven Sampling Periods From November 1992 to May 1994 (Numerals indicate the number of samples in which taxa occurred out of seven samples collected)

Family Species	*Spartina* Zone		*Juncus* Zone	
	Natural	Constructed	Natural	Constructed
Cyprindodontidae				
Fundulus grandis Baird and Girard	7	7	5	6
Fundulus pulvereus (Evermann)	7	7	7	7
Fundulus similis (Baird and Girard)	1	3	3	5
Adenia xenica (Jordan and Gilbert)	7	7	7	7
Cyprinodon variegatus Lacecede	6	5	7	7
Lucania parva (Baird)				1
Poecillidae				
Poecilia latipinna (Lesueur)	7	6	6	7
Gambusia affinis (Baird and Girard)	4	2	2	5
Atherinidae				
Menidia beryllina (Cope)	6	6	5	6
Eleotridae				
Dormitator maculatus (Richardson)				1
Gobiidae				
Gobionellus shufeldti (Jordon and Eigenmann)	3	1	1	4
Clupeidae				
Brevoortia patronus Goode	3	3	2	
Mugilidae				
Mugil cephalus Linnaeus	6	7	5	7
Mugil curema Valenciennes	2	1	2	1
Sciaenidae				
Leiostomus xanthurus Lacepede	4	4	3	3
Micropogon undulatus (Linnaeus)	1	0		
Cynoscion nebulosus (Cuvier)	1	1		
Sparidae				
Lagodon rhomboides (Linnaeus)	4	4		3
Carangidae				
Caranx hippos (Linnaeus)		2		
Bothidae				
Paralichthys lethostigma Jordan and Gilbert	1	3	1	2
Engraulidae				
Anchoa mitchelli (Valenciennes)		3		
Synodontidae				
Synodus foetens (Linnaeus)	1	2		
Ariidae				
Arius felis (Linnaeus)		1		

(Continued)

Table 14 (Concluded)				
Family Species	*Spartina* Zone		*Juncus* Zone	
	Natural	Constructed	Natural	Constructed
Palaeomontidae				
Palaemonetes pugio Holthuis	7	7	7	7
Penaeidae				
Penaeus setiferus (Linnaeus)	1	1	1	1
Penaeus aztecus Ives	3	4	2	4
Portunidae				
Callinectes sapidus Rathbun	7	7	4	7
Total Number of Species	22	24	18	20
Similarity (C)	0.95		0.89	

white shrimp in fall). Species equitability (1-d) was higher in the natural marsh for most sampling periods. The lower values in the constructed marsh were caused by the high numbers of grass shrimp that acted to reduce the value of 1-d. Similarity between marshes was very high overall ($C > 0.80$) due to the larger number of species common to both marshes.

The *Spartina* assemblages of both marshes were composed of a similar suite of fishes and shellfish, including a suite of year-round resident species (e.g., grass shrimp and several species of killifishes) and the seasonally occurring juveniles of estuarine transient species (e.g., spot, brown, and white shrimp). Commonly occurring resident species (defined as occurring in at least five of the seven sampling periods in either marsh) included *Fundulus grandis*, *Fundulus pulvereus*, *Adenia xenica*, *Cyprinodon variegatus*, *Poecilia latipinna*, *Menidia beryllina*, *Mugil cephalus* (juveniles and subadults), *Palaemonetes pugio*, and *Callinectes sapidus*. Commonly occurring transient species (occurring as dominant seasonal components of an assemblage) in both marshes included *Brevoortia patronus*, *Leiostomus xanthurus*, *Lagodon rhomboides*, *Penaeus setiferus*, and *Penaeus aztecus*. Three species of fishes were collected only in the constructed marsh (*Caranx hippos*, *Anchoa mitchelli*, and *Arius felis*), while one species was found only in the natural marsh (*Micropogon undulatus*).

The most dominant organism overall was the grass shrimp *Palaemonetes pugio*, which comprised from 18.6 to 77.7 percent of the natural marsh and from 36.1 o 96.2 percent of the constructed marsh assemblages. Killifishes dominated the fish component of both assemblages in the fall (November 1992, September 1993) and early spring (March 1993) periods. Estuarine transient species dominated both assemblages in the spring (April and May 1993 and 1994) and fall periods (white shrimp in September). Although total organism density was consistently higher in the constructed marsh (ranging from 1.6 to 18.3 times), these values were not significantly different from natural marsh levels; values were nearly different, however, in November 1992 ($P = 0.06$) and April and May 1994 ($P = 0.07$). High variability also

Table 15
Mean Densities (± SD) of Nektonic Organisms in the *Spartina* Zones of the Natural and Constructed Marsh Sites Over Seven Sampling Periods From November 1992 to May 1994

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Fundulus grandis (7/5)	**3.5** (3.5)	**13.5** (2.1)	4.5 (2.1)	**25**	0.5 (0.7)		1.0*** (0.0)		5.0* (0.0)	0.5 (0.7)	**2.5** (0.7)	0.5 (0.7)	2.0 (2.8)	3.5 (4.9)
Fundulus pulvereus (7/7)	2.5 (0.7)	1.5 (0.7)	**43.5** (28.9)	**39**	**2.0** (1.4)	1.5 (2.1)	**39.5** (44.5)	1.5 (0.7)	**19.0** (12.7)	**12.0** (8.4)	**5.0** (2.8)	2.0 (1.4)	**56.0** (52.3)	**29.5** (37.4)
Fundulus similis (1/3)		1.0 (0.0)		8					0.5 (0.7)	**2.5** (3.5)				
Adenia xenica (7/7)	**4.0** (5.6)	**10.0** (5.6)	**29.0** (18.3)	**56**	**10.5** (3.5)	1.5 (2.1)	7.5[4] (3.5)	1.5 (0.7)	**13.5** (10.6)	**6.5** (2.1)	2.0 (1.4)	1.0 (1.4)	3.5 (3.5)	4.0 (2.8)
Cyprinodon variegatus (6/5)	**33.0** (32.5)	**11.5** (10.6)	**6.5** (2.1)	**23**	1.0 (1.4)	(1.5) (0.7)	**20.0** (8.4)	**5.5** (4.9)	**14.5*** (9.1)				**23.0** (11.3)	**6.5** (6.3)
Poecilia latipinna (7/6)	**19.0** (26.8)	**2.5** (0.7)	**10.5** (4.9)	1	1.0 (1.4)	0.5 (0.7)	3.0 (1.4)	**4.0** (4.2)	**17.0** (24.0)	0.5 (0.7)	0.5 (0.7)		2.0 (0.0)	2.5 (2.1)
Gambusia affinis (4/2)					0.5 (0.7)				1.5 (2.1)	**4.5** (6.3)	0.5 (0.7)		0.5 (0.7)	2.0 (0.0)
Menidia beryllina (6/6)	1.5 (2.1)	**4.5** (0.7)			**2.5** (3.5)	1.0 (0.0)	**19.0** (26.8)	**5.5** (7.7)	0.5 (0.7)	1.0 (1.4)	**21.0** (4.2)	**18.0** (11.3)	**12.5** (17.6)	**6.0** (8.4)
Gobionellus shufeldti (3/1)			0.5 (0.7)				0.5 (0.7)		0.5 (0.7)					0.5 (0.7)
Brevoortia patronus (3/3)					**5.0** (4.2)	**21.5** (30.4)	**15.5** (20.5)	**7.5** (10.6)					**15.0** (21.2)	**7.5** (10.6)
Mugil cephalus (6/7)	2.0 (2.8)	**2.5** (2.1)	1.0 (1.4)	**32**	1.5 (2.1)	**34.0** (39.5)	**63.5** (45.9)	**17.0** (18.3)	**17.0** (24.0)	**2.0** (1.4)		0.5 (0.7)	**51.0** (66.4)	3.0 (1.4)
Mugil curema (2/1)	0.5 (0.7)								**12.0** (16.9)	0.5 (0.7)				
Leiostomus xanthurus (4/4)					**7.0** (0.0)	**54.5*** ** (14.8)	**32.0** (14.1)	**25.0** (14.1)			**8.5** (2.1)	**45.5** (55.8)	**20.0** (25.4)	**26.5** (21.9)
Micropogon undulatus (1/0)													1.0 (1.4)	

(Continued)

Note: All data are from flume weir samples (100 m^2). Bolded values signify common organisms in each sample ($\geq$5 percent of total density, calculated separately for fish and shellfish). Numerals in parentheses below species names indicate frequency of occurrence in both sites (natural/constructed). Values for species richness, species equitability (1-d), and coefficents of similarity (C) are also provided. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 15 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Cynoscion nebulosus (1/1)									0.5 (0.7)	0.5 (0.7)				
Lagodon rhomboides (4/4)					**2.5** (3.5)	**12.5** (13.4)	3.5 (3.5)	**25.0** (14.1)			0.5 (0.7)	**9.5*** (3.5)	3.5 (4.9)	**18.0** (24.0)
Caranx hippos (0/2)								1.0 (1.4)						1.0 (1.4)
Paralichthys lethostigma (1/3)							0.5 (0.7)	**5.5**[3] (2.1)				0.5 (0.7)		3.0* (1.4)
Anchoa mitchelli (0/3)								**4.0** (5.6)		0.5 (0.7)				4.0 (5.6)
Synodus foetens (1/2)								0.5 (0.7)					7.5 (10.6)	0.5 (0.7)
Arius felis (0/1)										0.5 (0.7)				
Unid. fish larvae					5.0* (2.8)		25.5 (36.0)	1.0 (0.0)	4.0 (0.0)	8.0 (7.0)	6.5 (6.3)	6.5 (9.1)	20.0 (24.0)	0.5 (0.7)
Leptocephalus larvae					1.0 (1.4)						1.0 (1.4)			
Palaemonetes pugio (7/7)	**15.5** (21.9)	**1,467.5**[4] (307.5)	**337.5** (239.7)	**1,907**	**123.5** (92.6)	**109.5** (102.5)	**113.5** (16.2)	**253.0*** (42.4)	**153.5** (144.9)	**353.0** (125.8)	**134.5** (21.9)	**711.5*** (338.7)	**104.5** (53.0)	**454.0**[2] (120.2)
Penaeus setiferus (1/1)									**23.5** (4.9)	**190.0**** (19.7)				
Penaeus aztecus (3/4)						**21.0*** (12.7)	**67.5** (12.0)	**339.0*** (124.4)			**28.5** (13.4)	**71.0** (8.4)	**50.0** (41.0)	**432.5**[3] (123.7)
Callinectes sapidus (7/7)	1.5 (2.1)	**9.0** (5.6)	1.0 (1.4)	7	1.0 (1.4)	5.5 (0.7)	1.5 (0.7)	3.0 (1.4)	2.0 (1.4)	**11.0*** (1.4)	2.0 (0.0)	2.0 (0.0)	1.5 (0.7)	3.0 (1.4)
Total Organisms	83.0 (82.0)	1,525.0[2] (332.3)	434.0 (247.4)	2,098	164.5 (108.1)	264.5 (194.4)	413.5 (43.1)	699.5 (208.5)	284.5 (249.6)	593.5 (125.1)	213.0 (36.7)	868.5[3] (429.2)	373.5 (149.1)	1,008.0[3] (39.5)
Species Richness	10	10	9	9	13	12	15	16	15	15	11	11	16	19
Equitability (1-d)	0.60	0.03	0.22	0.09	0.24	0.58	0.72	0.51	0.46	0.40	0.36	0.18	0.72	0.54
Similarity (C)	0.90		0.88		0.88		0.83		0.86		0.81		0.85	

limited the statistical separation for most organisms showing trends in either marsh. Overall, resident species of fishes showed a tendency to be more abundant in the natural marsh, while estuarine transient fishes and shrimp tended to be found at higher levels in the constructed marsh. Organisms showing significantly higher densities in the natural marsh included *Fundulus grandis* (May and September 1993) and *Cyprinodon variegatus* (September 1993). Organisms with significantly greater densities in the constructed marsh included *Leiostomus xanthurus* (April 1993), *Lagodon rhomboides* (April 1994), *Paralichthys lethostigma* (May 1994, large numbers present May 1993), *Palaemontetes pugio* (May 1993, April 1994, large numbers present November 1992 and May 1994), *Penaeus setiferus* (September 1993), *Penaeus aztecus* (April and May 1993, large numbers present May 1994), and *Callinectes sapidus* (September 1993). *Adenia xenica* was present in high numbers in the natural marsh in May 1993.

Patterns of organism biomass within the *Spartina* zone assemblages (Table 16) were affected by both the relative numbers and size of organisms, but were nonetheless, more similar than those patterns shown for density. Killifishes and mullet species (*Mugil cephalus* and *Mugil curema*) dominated fall (November 1992, September 1993) and early spring (March 1993) samples, while spring samples (April and May of 1993 and 1994) were dominated by mullet and selected estuarine transient species (*Leiostomus xanthurus*, *Lagodon rhomboides*, and *Penaeus setiferus* and *Penaeus aztecus*). Mullet (juveniles and subadults) were generally larger than most other fishes collected. Killifish species, spot, white shrimp, and brown shrimp were smaller than mullet, but occurred at densities that offset the size difference in biomass contribution. Grass shrimp are much smaller than most fishes or larger shellfish and, despite their larger numbers, contributed little to overall biomass. As with total density, total organism biomass was consistently higher in the constructed marsh (ranging from 1.9 to 5.4 times), but was significantly so in only one sampling period (April 1994). Organisms showing significantly greater biomass in the constructed marsh included *Fundulus grandis* (November 1992), *Fundulus similis* (November 1992), *Mugil cephalus* (April 1993), *Leiostomus xanthurus* (April 1993), *Lagodon rhomboides* (April 1994), *Paralichthys lethostigma* (May 1994), *Palaemonetes pugio* (November 1992, May 1993, April and May 1994), and *Penaeus setiferus* (September 1993). *Penaeus aztecus* had greater biomass in April and May 1993 and in May 1994, *Callinectes sapidus* in November 1992. One organism had significantly greater biomass in the natural marsh (*Fundulus grandis*, May 1993, large numbers present in September 1993), while two others had greater biomass there (*Fundulus pulvereus* in September 1993 and *Adenia xenica* in April 1993).

The *Juncus* zone nekton assemblages of both the natural and constructed marshes (Table 17) were similar in terms of species richness overall (18 species in the natural marsh, 20 species in the constructed marsh), but differed across sampling periods. Richness was higher in the constructed marsh in six of the seven sampling events, with substantial differences in richness (from

Table 16
Mean Biomass (grams) (± SD) of Nektonic Organisms in the *Spartina* Zones of the Natural and Constructed Marsh Sites Over Seven Sampling Periods From November 1992 to May 1994

	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
Species	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Fundulus grandis	**6.9** (3.6)	**44.9*** (10.3)	**25.6** (17.3)	**74.9**	**4.4** (6.2)		7.3*** (0.2)		**30.2**[3] **(3.8)**	1.8 (2.5)	**11.0** (2.5)	1.8 (2.6)	5.0 (7.1)	**29.8** (42.1)
Fundulus pulvereus	0.2 (0.2)	0.4 (0.1)	**9.9** (8.0)	**12.5**	0.8 (0.3)	0.5 (0.7)	5.2 (6.2)	0.3 (0.0)	8.3[4] (1.2)	5.9 (0.2)	0.5 (0.4)	1.3 (1.2)	**10.5** (9.1)	**11.1** (14.7)
Fundulus similis		2.1* (0.8)		**33.2**					0.7 (0.9)	2.0 (2.8)				
Adenia xenica	0.8 (1.1)	0.9 (0.4)	**3.3** (2.4)	**18.5**	**1.9**[3] (0.2)	0.3 (0.4)	2.3 (1.6)	0.5 (0.2)	2.4 (1.6)	1.6 (0.4)	1.4 (0.8)	0.5 (0.7)	1.7 (1.8)	1.9 (1.7)
Cyprinodon variegatus	**18.0** (20.0)	**3.9** (1.3)	**3.4** (0.3)	**17.9**	**2.0** (2.8)	1.1 (0.07)	5.0 (2.4)	4.7 (4.2)	4.7 (1.2)				8.2 (6.5)	6.3 (5.4)
Poecilia latipinna	**3.7** (5.3)	0.5 (0.2)	**3.0** (1.2)	0.2	0.2 (0.2)	1.0 (0.2)	2.0 (0.5)	3.2 (3.4)	9.4 (13.2)	0.1 (0.2)	0.4 (0.5)		1.8 (0.9)	1.7 (1.9)
Gambusia affinis									0.6 (0.9)	1.0 (1.4)	0.2 (0.3)		0.1 (0.2)	2.3 (1.6)
Menidia beryllina	2.1 (3.0)	**4.1** (1.6)			**1.8** (2.5)	0.8 (0.1)	5.0 (7.1)	2.0 (2.8)	0.5 (0.7)	0.9 (1.2)	**3.1** (3.2)	0.6 (0.2)	4.6 (6.5)	2.2 (3.1)
Gobionellus shufeldti		0.3 (0.4)	1.7 (2.4)				0.05 (0.07)		2.0 (2.8)					0.1 (0.2)
Brevoortia patronus					**1.2** (1.1)	**4.0** (5.6)	4.7 (6.3)	3.6 (5.1)					5.2 (7.3)	3.6 (5.1)
Mugil cephalus	**28.1** 39.8	**11.9** (15.8)	0.1 (0.2)	7.4	0.8 (1.1)	**31.1*** (20.2)	**122.9** (139.7)	**15.5** (10.6)	**218.3** (308.7)	**371.4** (502.8)		1.7 (2.4)	**122.7** (169.4)	4.3 (4.7)
Mugil curema	**7.5** (10.6)								**179.3** (253.6)	8.6 (12.1)				
Leiostomus xanthurus					**3.7** (0.7)	**30.6**** (2.0)	**32.9** (18.6)	**45.7** (35.2)			**13.6** (0.07)	**73.0** (84.1)	**22.7** (29.6)	**50.5** (48.9)
Micropogon undulatus													0.7 (1.0)	

(Continued)

Note: All data are from flume weir samples (100 m^2). Bolded values signify organisms in each sample that contributed ≥5 percent of total biomass, calculated separately for fish and shellfish. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 16 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Cynoscion nebulosus									2.8 (4.0)	0.6 (0.9)				
Lagodon rhomboides					1.1 (1.5)	**4.9** (3.8)	4.8 (5.4)	**50.1** (38.2)			0.7 (0.9)	**11.6*** (3.7)	4.8 (6.8)	**38.3** (52.9)
Caranx hippos								0.6 (0.8)						0.6 (0.8)
Paralichthys lethostigma							0.6 (0.9)	2.7 (1.3)				1.5 (2.1)		2.0** (0.4)
Anchoa mitchelli								3.7 (5.3)		0.05 (0.07)				3.9 (5.5)
Synodus foetens								0.4 (0.5)					0.9 (1.3)	0.3 (0.4)
Arius felis										**30.8** (43.5)				
Unid. fish larvae					0.1 (0.2)		1.5 (2.1)	0.02 (0.02)	0.07 (0.04)	0.1 (0.1)	0.05 (0.07)	0.1 (0.2)	0.02 (0.03)	
Leptocephalus larvae					0.05 (0.07)						0.05 (0.07)			
Palaemonetes pugio	2.1 (3.0)	153.1* (19.0)	35.2 (29.9)	218.7	17.5 (11.3)	14.6 (10.9)	15.6 (1.7)	49.3* (12.9)	10.1 (7.7)	27.3 (10.4)	20.5 (0.4)	147.5* (77.2)	17.2 (8.2)	67.0* (7.8)
Penaeus setiferus									28.6 (4.5)	102.0* (36.6)				
Penaeus aztecus						2.7[5] (2.0)	**53.1** (15.0)	**250.7**[4] (141.9)			**38.8** (17.4)	49.7 (17.8)	**44.1** (39.8)	**392.4**[4] (82.8)
Callinectes sapidus	2.7 (3.8)	91.7[2] (11.9)	2.0 (2.8)	76.2	4.6 (6.5)	8.7 (1.1)	11.7 (8.0)	146.0 (183.2)	5.1 (6.7)	446.0 (591.7)	8.0 (9.8)	141.0 (198.3)	7.3 (9.4)	71.6 (75.8)
Total Biomass	72.4 (61.0)	314.0 (24.6)	84.4 (11.9)	459.5	40.4 (19.9)	99.7 (2.5)	275.0 (173.1)	579.5 (55.7)	503.5 (581.3)	1,000.3 (1,109.5)	98.6 (0.9)	430.6*** (15.7)	258.0 (256.2)	690.4 (67.4)

Table 17

Mean Densities (± SD) of Nektonic Organisms in the *Juncus* Zones of the Natural and Constructed Marsh Sites Over Seven Sampling Periods From November 1992 to May 1994

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Fundulus grandis (5/6)	**30.5** (27.5)	**16.0** (21.2)		**31.5**** (9.1)		4.5[4] (3.5)	3.5 (2.1)	**4.0** (5.6)	0.5 (0.7)	**20**	1.0 (0.0)	3.0 (1.4)	0.5 (0.7)	
Fundulus pulvereus (7/7)	**22.0** (25.4)	2.0 (2.8)	**26.0** (14.1)	**59.5** (13.4)	**6.5** (0.7)	**64.5**[4] (50.2)	**7.5** (2.1)	**7.5** (0.7)	**5.0** (0.0)	**99**	**5.0** (1.4)	**14.5** (9.1)	**15.5** (0.7)	**72.5** (72.8)
Fundulus similis (3/5)	2.5 (2.1)			4.0** (1.4)		0.5 (0.7)			0.5 (0.7)	9	1.0 (0.0)	**4.5** (3.5)		1.5* (0.7)
Adenia xenica (7/7)	**32.5** (31.8)	2.0 (2.8)	**2.0** (1.4)	**74.0**** (26.8)	**12.0** (15.5)	**64.0** (21.2)	**29.5** (14.8)	**7.5** (3.5)	**5.5** (0.7)	**35**	**8.5**[3] (0.7)	2.0 (1.4)	**23.0** (11.3)	**13.0** (14.1)
Cyprinodon variegatus (7/7)	**13.5** (13.4)	**13.5** (7.7)	**2.5** (0.7)	**166.5**** (51.6)	1.0 (1.4)	**19.0*** (4.2)	**5.0** (1.4)	**9.5** (3.5)	**14.5** (0.7)	7	**2.5** (3.5)	**11.5** (10.6)	**8.5** (2.1)	**49.0** (52.3)
Lucania parva (0/1)						0.5 (0.7)								
Poecilia latipinna (6/7)	**12.0** (12.7)	**9.5** (13.4)	**3.5** (2.1)	6.5 (7.7)	1.0 (1.4)	**13.0** (9.8)	**9.0** (5.6)	**4.0** (1.4)	**31.5** (20.5)	**12**		4.0 (4.2)	2.5 (3.5)	3.0 (1.4)
Gambusia affinis (2/5)						4.0 (5.6)		0.5 (0.7)	0.5 (0.7)	4		1.0*** (0.0)	1.5 (1.2)	0.5 (0.7)
Menidia beryllina (5/6)	1.5 (0.7)	0.5 (0.7)				2.5 (3.5)	**10.0** (7.0)	**4.5** (2.1)	1.5 (0.7)	8	**2.0** (2.8)	**14.0** (2.8)	**8.0** (11.3)	1.5 (0.7)
Dormitator maculatus (0/1)										1				
Gobionellus shufeldti (1/4)		1.0 (1.4)								1	0.5 (0.7)	1.5 (2.1)		0.5 (0.7)
Brevoortia patronus (2/0)							0.5 (0.7)						0.5 (0.7)	
Mugil cephalus (5/7)	0.5 (0.7)	0.5 (0.7)	0.5 (0.7)	0.5 (0.7)		2.5** (0.7)	**15.0** (18.3)	**6.5** (6.3)	**16.5** (3.5)	4.0		0.5 (0.7)	**14.0** (19.7)	5.5 (7.7)

(Continued)

Note: All data are from flume weir samples (100 m^2). Bolded values signify common organisms in each sample ($\geq$5 percent of total density, calculated separately for fish and shellfish). Numerals in parentheses below species names indicate frequency of occurrence in both sites (natural/constructed). Values for species richness, species equitability (1-d), and coefficents of similarity (C) are also provided. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 17 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Mugil curema (2/1)	1.5 (2.1)								**17.0** (1.4)	3				
Leiostomus xanthurus (3/3)							**13.0** (18.3)	**4.0** (2.8)			1.0 (1.4)	**23.5*** (2.1)	**13.0** (18.3)	3.0 (4.2)
Lagodon rhomboides (0/3)								**3.0** (4.2)				1.5 (2.1)		2.0 (2.8)
Paralichthys lethostigma (1/2)								0.5 (0.7)			0.5 (0.7)			2.5 (2.1)
Unid. fish larvae					2.0 (1.4)	**11.5** (10.6)	1.0 (0.0)	0.5 (0.7)	1.0 (1.4)	**14**	**2.5** (3.5)	**6.0** (7.0)	4.5 (6.3)	6.5 (4.9)
Leptocephalus larvae					0.5 (0.7)						0.5 (0.7)	0.5 (0.7)		
Palaemonetes pugio (7/7)	6.5 (9.1)	30.0 (42.4)	65.0 (45.2)	406.5[4] (168.9)	7.0 (8.4)	520.5* (99.7)	46.0 (38.1)	74.0 (14.1)	**14.0** (14.1)	104	37.5 (23.3)	197.0 (125.8)	43.0 (56.5)	105.5 (4.9)
Penaeus setiferus (1/1)									47.5 (2.1)	22				
Penaeus aztecus (2/4)						1.5 (2.1)	33.5 (26.1)	15.0 (15.5)				9.5 (10.6)	31.0 (32.5)	14.5 (16.2)
Callinectes sapidus (4/7)	1.5 (0.7)	1.0 (1.4)		1.5* (0.7)		3.0* (1.4)	0.5 (0.7)	1.0 (1.4)	1.0 (1.4)	4		0.5 (0.7)	2.0 (0.0)	1.5 (2.1)
Total Organisms	124.5 (40.3)	76.0 (5.6)	99.5 (33.2)	750.5** (101.1)	30.0 (28.2)	711.5* (40.3)	174.0 (120.2)	142.0 (2.8)	156.5 (2.1)	347	62.5 (26.1)	295.0[3] (131.5)	167.5 (147.7)	282.5 (120.9)
Species Richness	11	10	6	9	5	13	12	14	13	15	10	15	13	15
Equitability (1-d)	0.73	0.60	0.34	0.45	0.60	0.26	0.73	0.47	0.69	0.71	0.40	0.33	0.74	0.62
Similarity	0.85		0.80		0.55		0.84		0.92		0.72		0.78	

33.3 to 61.5 percent lower) occurring in three periods (March, April, and September 1993). As with the *Spartina* zone assemblages, richness was highest in spring (April and May of 1993 and 1994) and fall (September), in large part because of the seasonal occurrence of estuarine transient species. Species equitability (1-d) was higher overall in the natural marsh for most sampling periods (five of seven), but equitability was more comparable between marshes than that observed for the *Spartina* zone assemblages. Similarity between marshes was very high overall ($C > 0.70$ in six of seven periods), due to the large number of species common to both marshes.

As in the Spartina zone, the *Juncus* assemblages of both marshes were composed of a similar suite of fishes and shellfish, including a suite of year-round resident species (e.g., grass shrimp and killifishes) and the seasonally occurring juveniles of estuarine transient species (e.g., spot, brown, and white shrimp). Commonly occurring resident species (defined as occurring in at least five of the seven sampling periods in either marsh) included *Fundulus grandis*, *Fundulus pulvereus*, *Fundulus similis* (constructed marsh), *Adenia xenica*, *Cyprinodon variegatus*, *Poecilia latipinna*, *Gambusia affinis* (constructed marsh), *Menidia beryllina*, *Mugil cephalus* (juveniles and subadults), *Palaemonetes pugio*, and *Callinectes sapidus*. Commonly occurring transient species (occurring as dominant seasonal components of an assemblage) included *Leiostomus xanthurus*, *Lagodon rhomboides* (constructed marsh), *Penaeus setiferus*, and *Penaeus aztecus*. Three species of fishes were collected only in the constructed marsh (*Lucania parvus*, *Dormitator maculatus*, and *Lagodon rhomboides*), while one species was found only in the natural marsh (*Brevoortia patronus*).

The grass shrimp, *Palaemonetes pugio*, was the dominant organism overall, as it was in the *Spartina* zone, comprising from 5.2 to 65.3 percent of the natural marsh and from 29.9 to 73.1 percent of the constructed marsh assemblages. Killifishes dominated the fish component of both assemblages in all seven sampling periods with estuarine transient species becoming important components in spring (May 1993 and April and May 1994) and fall periods (white shrimp in September). Except for November 1992 and May 1993, total organism density was higher in the constructed marsh (ranging from 1.6 to 23.7 times), with significantly higher values in March and April 1993 and a higher value in April 1994 ($P = 0.07$). High variability limited the statistical separation for most organisms showing trends in either marsh. Unlike in the *Spartina* zone, however, resident species of fishes showed a tendency to be more abundant in the constructed marsh, and transient fishes and shrimp tended to be found at higher levels in the natural marsh. Organisms showing significantly higher densities in the constructed marsh included *Fundulus grandis* (March 1993, large numbers present in April 1993), *Fundulus similis* (March 1993, May 1994), *Adenia xenica* (March 1993), *Cyprinodon variegatus* (March and April 1993), *Gambusia affinis* April 1994), *Mugil cephalis* (April 1993), *Leiostomus xanthurus* (April 1994), *Palaemonetes pugio* (April 1993, large numbers present in March 1993), and *Callinectes sapidus* (March and April 1993). *Fundulus pulvereus* was greater ($P = 0.08$) in the

constructed marsh in April 1993. *Adenia xenica* was greater in the natural marsh (P = 0.07).

As in the *Spartina* zone, patterns of organism biomass within the *Juncus* zone assemblages (Table 18) was affected by both the relative numbers and size of organisms. Except for the relatively minor contribution by *Palaemonetes pugio*, however, the same general suite of organisms contributed to biomass as they did to density. Killifishes contributed to biomass across all seven sampling periods, while large-bodied species, such as *Mugil cephalus*, *Mugil curema*, and *Paralichthys lethostigma*, and seasonally abundant estuarine transients, such as *Leiostomus xanthurus*, *Lagodon rhomboides*, *Penaeus setiferus*, and *Penaeus aztecus*, contributed to spring (May 1993, April and May 1994) and fall samples (September 1993). Grass shrimp, while numerically dominant in this marsh type, contributed relatively little to overall biomass. Total organism biomass was significantly greater in the constructed marsh in three sampling periods, ranging from 4 to 26.0 times that of the natural marsh. Biomass was greater (but not significantly different) in the natural marsh in four samples ranging from 1.1 to 1.4 times that of the constructed marsh. Organisms showing significantly greater biomass in the constructed marsh included *Fundulus grandis* (March 1993), *Fundulus pulvereus* (March 1993), *Fundulus similis* (March 1993), *Adenia xenica* (March 1993), *Cyprinodon variegatus* (March and April 1993), *Menidia beryllina* (April 1994), *Mugil cephalus* (April 1993), *Leiostomus xanthurus* (April 1994), *Palaemonetes pugio* (March and April 1993), and *Callinectes sapidus* (April 1993). One organism had significantly greater biomass in the natural marsh (*Fundulus similis*, November 1992), while one other had nearly significantly greater biomass there (*Adenia xenica* in May 1993).

Lift net samples

A total of 12 species of fish (six families) and 4 species of shellfish (shrimps and crabs) were identified from lift net samples in the lower and upper portions of the *Juncus* zone of the constructed marsh (Table 19). Three species of fish were found only in the upper creek area (*Gambusia affinis*, *Mugil cephalus*, *Mugil curema*), while two species of fish (*Fundulus similis* and *Gobionellus shufeldti*) and one species of shellfish (*Penaeus aztecus*) were found only in the lower creek area. Killifishes and grass shrimp dominated both areas in all seven sampling periods, with estuarine transient species appearing on a seasonal basis. Both areas had equal overall species richness (13 species), but richness differed between areas within selected samples. Richness was most similar in the spring periods of both years, while the greatest difference in richness occurred in the fall of both years and in the April sample of 1994. Species equitability was moderate (1-d = 0.3) to relatively high (1-d = 1.0) in both areas with no obvious pattern within either area. Similarity between areas was relatively high ($C > 0.50$) in most samples (five of seven).

Table 18
Mean Biomass (grams) (± SD) of Nektonic Organisms in the *Juncus* Zones of the Natural and Constructed Marsh Sites Over Seven Sampling Periods From November 1992 to May 1994

	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
Species	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Fundulus grandis	**96.0** (116.1)	**86.7** (122.1)		**130.5**** (32.1)		**25.5** (30.1)	**14.0** (9.4)	**40.5** (19.1)	5.3 (7.4)	**50.9**	**6.7** (3.3)	**20.3** (5.2)	2.3 (3.2)	
Fundulus pulvereus	**8.8** (9.6)	1.0 (1.4)	**7.7** (2.1)	18.2* (1.8)	**1.8** (0.07)	**14.8** (10.5)	4.2 (2.1)	3.4 (0.07)	1.5 (0.1)	**70.4**	**4.8** (1.1)	**14.4** (18.3)	**6.4** (3.3)	**13.3** (4.6)
Fundulus similis	2.1* (0.5)			11.1*** (0.9)		1.4 (2.0)			1.2 (1.6)	7.4	**9.3** (1.8)	**21.9** (18.1)		**6.8** (9.4)
Adenia xenica	5.8 (4.8)	0.4 (0.6)	0.4 (0.1)	**28.9*** (15.5)	**2.1** (2.8)	**17.1** (8.0)	**14.4**[5] (8.9)	1.8 (1.3)	1.1 (0.2)	7.7	**3.8** (0.6)	1.2 (0.9)	**11.6** (8.4)	**4.8** (5.3)
Cyprinodon variegatus	**13.1** (16.8)	**10.1** (11.7)	**0.9** (0.3)	**231.5*** (207.6)	**1.2** (1.7)	**14.0**[5] (4.9)	2.7 (1.6)	**10.5** (5.0)	9.9 (0.2)	1.1	1.5 (2.1)	**11.5** (5.5)	1.5 (1.4)	**8.3** (2.7)
Lucania parva						0.05 (0.07)								
Poecilia latipinna	5.8 (1.2)	**8.8** (12.5)	**1.7** (2.1)	1.6 (2.0)	0.2 (0.2)	**5.1** (4.4)	**9.6** (6.2)	3.1 (2.1)	**28.2** (22.0)	9.4		2.8 (2.4)	2.5 (3.6)	2.3 (2.3)
Gambusia affinis						0.6 (0.8)		0.2 (0.3)	0.05 (0.07)	0.9		0.4 (0.4)	0.6 (0.8)	0.2 (0.2)
Menidia beryllina	1.0 (0.4)	0.5 (0.7)				2.8 (4.0)	**6.0** (6.4)	2.5 (3.4)	1.1 (0.4)	6.9	0.04 (0.06)	3.7* (1.3)	**5.2** (7.3)	0.5 (0.5)
Dormitator maculatus										6.4				
Gobionellus shufeldti		0.1 (0.1)								3.3	1.4 (1.9)	3.5 (5.0)		1.2 (1.7)

(Continued)

Note: All data are from flume weir samples (100 m^2). Bolded values signify organisms in each sample that contributed ≥5 percent of total biomass, calculated separately for fish and shellfish. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 18 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con	Nat	Con
Brevoortia patronus							0.2 (0.2)						0.2 (0.2)	
Mugil cephalus	4.4 (6.2)	0.05 (0.07)	0.1 (0.1)	0.05 (0.07)		0.3* (0.07)	**24.3** (31.3)	**6.0** (7.9)	**184.2** (45.1)	**44.5**		0.1 (0.1)	**23.0** (32.5)	**5.6** (7.9)
Mugil curema	**17.0** (24.0)								**192.6** (13.0)	**58.7**				
Leiostomus xanthurus							**17.0** (24.1)	**7.6** (5.0)			1.0 (1.4)	**28.9*** (14.5)	**16.5** (23.3)	**5.3** (7.5)
Lagodon rhomboides								**5.4** (7.7)				3.0 (4.3)		**5.2** (7.4)
Paralichthys lethostigma								0.1 (0.2)			**3.3** (4.6)			**3.6** (4.6)
Unid. fish larvae					0.03 (0.02)	0.07 (0.03)	0.02 (0.02)	0.005 (0.007)	0.005 (0.007)	0.2				0.05 (0.07)
Leptocephalus larvae					0.03 (0.04)						0.02 (0.03)	0.05 (0.07)		
Palaemonetes pugio	0.9 (1.2)	2.5 (3.5)	7.2 (5.3)	48.2[2] (7.0)	1.1 (1.4)	72.1* (10.2)	9.3 (7.6)	13.5 (4.8)	1.2 (1.4)	7.3	6.4 (4.5)	31.2 (22.2)	7.3 (9.7)	12.5 (6.8)
Penaeus setiferus									54.0 (8.1)	16.4				
Penaeus aztecus						0.01 (0.02)	43.1 (39.3)	24.1 (26.4)				12.0 (14.1)	41.3 (43.1)	22.9 (24.8)
Callinectes sapidus	6.8 (6.0)	10.8 (15.2)		0.6 (0.7)		1.3* (0.4)	3.5 (5.0)	11.5 (16.2)	3.6 (5.0)	47.7		0.4 (0.6)	34.7 (46.1)	27.9 (39.5)
Total Biomass	161.8 (140.0)	121.1 (160.8)	18.1 (5.1)	470.7* (244.7)	6.6 (6.5)	155.4* (19.0)	148.6 (107.9)	130.5 (0.3)	484.1 (30.4)	339.2	38.3 (2.4)	155.7* (36.4)	153.2 (183.4)	121.0 (13.0)

Table 19

Mean Densities (± SD) of Nektonic Organisms in the Lower and Upper Portions of the *Juncus* Zone of the Constructed Marsh Site Over Seven Sampling Periods From November 1992 to May 1994

	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
Species	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Fundulus grandis (2/3)	**1.5** (0.7)	0.5 (0.7)	**0.5** (0.7)	**5.5** (7.7)		0.5 (0.7)								
Fundulus pulvereus (7/6)	**0.5** (0.7)		**1.5** (0.7)	**8.0**[5] (4.2)	**1.0** (1.4)	**4.0** (4.2)	**1.5** (2.1)	**7.0** (2.8)	**5.5** (2.1)	**5.0** (4.2)	**2.0** (0.0)	**2.5** (0.7)	**6.5** (4.9)	**21.0** (16.9)
Fundulus similis (2/0)											0.5 (0.7)		**1.0***** (0.0)	
Adenia xenica (3/3)			**3.5** (4.9)	**14.5** (3.5)	**4.0** (1.4)	**1.5** (0.7)					0.5 (0.7)			1.0*** (0.0)
Cyprinodon variegatus (5/5)			**1.0** (1.4)	**1.5** (2.1)	**2.0** (2.8)	**5.5** (2.1)		**0.5** (0.7)	**2.0** (1.4)	**2.0** (1.4)	0.5 (0.7)		**1.0** (1.4)	1.0 (0.0)
Poecilia latipinna (3/2)	**0.5** (0.7)				**0.5** (0.7)		**0.5** (0.7)			**2.0** (2.8)				**1.5** (2.1)
Gambusia affinis (0/2)								**0.5** (0.7)		0.5 (0.7)				
Menidia beryllina (3/3)					**0.5** (0.7)	**1.5** (0.7)			**0.5** (0.7)	0.5 (0.7)	**4.0** (5.6)	**5.0** (5.6)		
Gobionellus shufeldti (3/0)	**0.5** (0.7)				**0.5** (0.7)						0.5 (0.7)			
Mugil cephalus (0/1)										0.5 (0.7)				

(Continued)

Note: All data are from lift net samples (6 m^2). Bolded values signify common organisms in each sample (≥5 percent of total density, calculated separately for fish and shellfish). Numerals in parentheses below species names indicate frequency of occurrence in both sites (natural/constructed). Values for species richness, species equitability (1-d), and coefficients of similarity (C) are also provided. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 19 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Mugil curema (0/1)										**1.5*** (0.7)				
Leiostomus xanthurus (1/3)								**0.5** (0.7)			**1.5** (2.1)	0.5 (0.7)		0.5 (0.7)
Unid. fish larvae					**1.0** (1.4)	**9.5** (10.6)		**1.0** (1.4)	**2.0** (2.8)	**1.0** (1.4)	**2.0** (2.8)	**4.0** (2.8)	**2.5** (3.5)	**5.0** (7.0)
Palaemonetes pugio (7/6)	3.0 (2.8)		15.0* (8.4)	0.5 (0.7)	21.5 (16.2)	3.5 (0.7)	2.0 (1.4)	3.5 (2.1)	3.5 (3.5)	9.5 (0.7)	8.0 (0.0)	25.5** (3.5)	3.5 (2.1)	1.5 (0.7)
Penaeus setiferus (1/1)									0.5 (0.7)	4.0 (5.6)				
Penaeus aztecus (2/0)							1.5 (2.1)						1.5 (2.1)	
Callinectes sapidus (4/2)			1.5 (2.1)	0.5 (0.7)					1.0 (0.0)	1.5 (2.1)	0.5 (0.7)		0.5 (0.7)	
Total Organisms	6.0 (4.2)	0.5 (0.7)	23.0 (18.3)	30.5 (6.3)	31.0 (25.4)	26.0 (8.4)	5.5 (4.9)	13.0 (1.4)	15.0 (4.2)	28.0 (4.2)	20.0 (2.8)	37.5* (2.1)	16.5 (4.9)	31.5 (24.7)
No. of Species	5	1	6	6	7	6	4	5	6	10	9	4	6	6
Equitability (1-d)	0.50	1.0	0.34	0.52	0.30	0.78	0.63	0.46	0.63	0.66	0.60	0.32	0.60	0.33
Similarity (C)	0.33		1.00		0.76		0.44		0.75		0.61		0.50	

Both assemblages were composed of a similar suite of fishes and shellfish, with year-round resident species (e.g., killifishes and grass shrimp) dominating most samples. Commonly occurring resident species (defined as occurring in at least five of the seven sampling periods in either area) included *Fundulus pulvereus*, *Cyprinodon variegatus*, and *Palaemonetes pugio*. *Penaeus setiferus* was present in both areas in the fall of 1993, but was dominant only in the upper area. *Penaeus aztecus* occurred in samples in the spring of both years sampled, but occurred only in the lower area. *Fundulus grandis*, *Adenia xenica*, *Menidia beryllina*, and *Callinectes sapidus*, while not common across sampling periods, dominated the assemblages of both areas when they occurred.

Fundulus pulvereus and *Palaemonetes pugio* were the most dominant organisms overall in both areas. Although not consistent across all sampling periods, both of these species showed trends toward being more abundant in one area over the other. *Fundulus pulvereus* was considerably more abundant (but not statistically significant) in the upper area in four of the seven sampling periods, whereas, *Palaemonetes pugio* was more abundant in the lower area in three samples (significantly so in March 1993) and considerably more abundant in the upper area in two others (significantly so in April 1994). Only three other species were found at significantly different levels between areas. In the lower area, *Fundulus similis* was more abundant in May 1994. In the upper area, *Adenia xenica* was found at greater density in May 1994 and *Mugil curema* at higher levels in September 1993. Total organism density was considerably higher in the upper zone in four periods (significantly so in April 1994) and higher in the lower zone in one sample.

Organism biomass within both areas (Table 20) followed a similar pattern as that for density. Unlike in flume weir samples, where large-bodied individuals of selected species had a proportionately greater effect on biomass values, the relatively equal size of the species that made up lift net samples minimized any differences between density and biomass patterns. *Palaemonetes pugio*, for example, contributed to biomass much as it did to total density. Killifish dominated the biomass in most cases except for the large contribution of *Mugil curema* to the upper area in September 1993, when it was significantly different from the lower area. Species showing significantly greater biomass in the upper area included *Adenia xenica* (May 1994), *Mugil curema* (September 1993), and *Palaemonetes pugio* (April 1994). *Adenia xenica* had nearly significantly greater biomass ($P = 0.06$) in the lower area in April 1993. Total biomass was significantly higher in the upper area in September 1993.

Flume weir/lift net comparisons

Direct comparisons of density estimates (standardized to a per square meter basis) for nekton collected by flume weirs and lift nets in the *Spartina* and *Juncus* zones of the natural marsh are shown in Tables 21 and 22, respectively. In the *Spartina* zone, the flume weir collected a greater number of species overall (22) compared with the lift net (14). Of the eight species that

Table 20
Mean Biomass (grams) (± SD) of Nektonic Organisms in the Lower and Upper Portions of the *Juncus* Zone of the Constructed Marsh Site Over Seven Sampling Periods From November 1992 to May 1994

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Fundulus grandis	**2.9** (2.5)	**0.8** (1.2)	**3.0** (4.2)	**26.4** (37.3)		**1.7** (2.4)								
Fundulus pulvereus	0.01 (0.01)		**0.4** (0.4)	**2.8** (3.1)	**0.7** (0.9)	**0.4** (0.3)	**0.1** (0.2)	**2.4** (1.5)	**1.3** (1.0)	**2.3** (1.9)	**0.6** (0.7)	**2.2** (2.8)	**2.7** (3.4)	**4.8** (4.5)
Fundulus similis											**1.6** (2.3)		**2.1** (2.6)	
Adenia xenica			**0.7** (0.9)	**2.7** (0.4)	**0.9**[2] (0.3)	0.1 (0.1)					**0.3** (0.4)			0.4** (0.07)
Cyprinodon variegatus			**0.7** (0.9)	0.8 (1.1)	**1.1** (1.6)	0.1 (0.0)		**0.5** (0.7)	0.06 (0.04)	0.3 (0.2)	**0.9** (1.2)		0.05 (0.07)	**0.5** (0.6)
Poecilia latipinna	0.05 (0.07)				0.2 (0.2)		**0.4** (0.5)			**1.8** (2.5)				**1.6** (2.3)
Gambusia affinis								0.2 (0.2)		0.05 (0.07)				
Menidia beryllina					**0.6** (0.8)	**1.8** (0.9)			**0.3** (0.4)	0.4 (0.5)	0.2 (0.2)	**0.4** (0.5)		
Gobionellus shufeldti	0.02 (0.03)				**0.7** (1.0)						**0.6** (0.9)			
Mugil cephalus										**3.8** (5.3)				

(Continued)

Note: All data are from lift net samples (6 m^2). Bolded values signify common organisms in each sample that contributed ≥5 percent of total biomass, calculated separately for fish and shellfish. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 20 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Mugil curema										**13.9**** (3.5)				
Leiostomus xanthurus								**1.7** (2.4)			**1.2** (1.6)	**1.2** (1.6)		**1.7** (2.4)
Unid. fish larvae					0.005 (0.007)	0.05 (0.06)		0.02 (0.03)	0.03 (0.04)	0.1 (0.2)	**0.4** (0.6)	0.05 (0.07)	0.01 (0.02)	0.1 (0.1)
Palaemonetes pugio	0.2 (0.2)		1.3 (0.9)	0.02 (0.02)	3.1 (3.1)	0.3 (0.07)	0.4 (0.1)	0.5 (0.2)	0.7 (0.9)	0.6 (0.07)	1.1 (0.0)	4.6* (0.8)	0.4 (0.5)	0.2 (0.1)
Penaeus setiferus (1/1)									1.7 (2.4)	2.1 (3.0)				
Penaeus aztecus							1.4 (2.0)						1.5 (2.1)	
Callinectes sapidus (4/2)			1.0 (1.4)	0.2 (0.3)					0.7 (1.0)	0.3 (0.4)	0.3 (0.4)		2.2 (3.1)	
Total Biomass	3.2 (2.2)	0.8 (1.2)	7.1 (8.9)	33.0 (33.8)	7.5 (8.3)	4.5 (1.4)	2.4 (1.8)	5.3 (1.6)	4.9 (1.0)	25.8* (4.5)	7.4 (7.0)	8.5 (6.0)	9.1 (5.0)	9.4 (3.6)

Table 21
Comparisons of Density Estimates (number per square meter) (± SD) of Nektonic Organisms Collected in Flume Weir and Lift Net Samplers in the *Spartina* Zone of the Natural Marsh Site Over Seven Sampling Periods From November 1992 to May 1994

	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
Species	Flume	Lift	Flume	Lift[1]	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift
Fundulus grandis (7/0)	0.035 (0.035)		0.045 (0.021)		0.005 (0.007)		0.010*** (0.000)		0.050*** (0.000)		0.025* (0.007)		0.020 (0.028)	
Fundulus pulvereus (7/5)	0.025 (0.007)	0.083 (0.117)	0.435 (0.289)	4	0.020 (0.014)		0.395 (0.445)	0.333 (0.235)	0.190 (0.127)	0.166 (0.235)	0.050 (0.028)		0.560 (0.523)	0.666 (0.707)
Fundulus similis (1/1)									0.005 (0.007)					0.083 (0.117)
Adenia xenica (7/1)	0.040 (0.056)		0.290 (0.183)		0.105 (0.035)	0.083 (0.117)	0.075^{5} (0.035)		0.135 (0.106)		0.020 (0.014)		0.035 (0.035)	
Cyprinodon variegatus (6/2)	0.330 (0.325)	0.166 (0.235)	0.065 (0.021)		0.010 (0.014)		0.200^{2} (0.084)		0.145 (0.091)				0.230 (0.113)	0.250 (0.353)
Poecilia latipinna (7/2)	0.190 (0.268)		0.105 (0.049)		0.010 (0.014)		0.030 (0.014)	0.083 (0.117)	0.170 (0.240)	0.166 (0.000)	0.005 (0.007)		0.020*** (0.000)	
Gambusia affinis (4/0)					0.005 (0.007)				0.015 (0.021)		0.005 (0.007)		0.005 (0.007)	
Menidia beryllina (6/3)	0.015 (0.021)				0.025 (0.035)	0.083 (0.117)	0.190 (0.268)		0.005 (0.007)	0.083 (0.117)	0.210 (0.042)	0.083 (0.117)	0.125 (0.176)	
Gobionellus shufeldti (3/0)			0.005 (0.007)				0.005 (0.007)		0.005 (0.007)					
Brevoortia patronus (3/0)					0.050 (0.042)		0.155 (0.205)						0.150 (0.212)	
Mugil cephalus (6/2)	0.020 (0.028)		0.010 (0.014)		0.015*** (0.021)		0.635 (0.459)	0.083 (0.117)	0.170 (0.240)				0.510 (0.664)	0.083 (0.117)
Mugil curema (2/1)	0.005 (0.007)								0.120 (0.169)	0.250 (0.117)				

(Continued)

Note: All data were corrected to a per square meter basis. Numerals in parentheses below species names indicate frequency of occurrence in samplers (flume weir/lift net). Values for species richness, species equitability (1-d), and coefficients of similarity (C) are also provided. * = Statistically significant at $p \leq 0.05 > 0.01$; ** = Statistically significant at $p \leq 0.01 > 0.001$; *** = Statistically significant at $p \leq 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 21 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Flume	Lift	Flume	Lift[1]	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift
Leiostomus xanthurus (4/2)					0.070 (0.000)		0.320 (0.141)	0.416 (0.117)			0.085* (0.021)		0.200 (0.254)	0.250 (0.353)
Micropogon undulatus													0.010 (0.014)	
Cynoscion nebulosus (1/0)									0.005 (0.007)					
Lagodon rhomboides (4/2)					0.025 (0.035)		0.035 (0.035)	0.250 (0.117)			0.005 (0.007)		0.035 (0.049)	0.166 (0.235)
Paralichthys lethostigma (1/0)							0.005 (0.007)							
Synodus foetens (1/0)													0.075 (0.106)	
Unid. fish larvae					0.050 (0.028)	0.083 (0.117)	0.255 (0.360)		0.040 (0.000)	0.583* (0.117)	0.065 (0.063)		0.200 (0.240)	0.583 (0.824)
Leptocephalus larvae					0.010 (0.014)						0.010 (0.014)			
Palaemonetes pugio (7/7)	0.155 (0.219)	0.416 (0.589)	3.375 (2.397)	11	1.235 (0.926)	0.750 (1.060)	1.135 (0.162)	0.833 (0.235)	1.535 (1.449)	3.500 (4.714)	1.345[5] (0.219)	0.250 (0.353)	1.045 (0.530)	2.083 (1.532)
Penaeus setiferus (1/1)									0.235 (0.049)	0.083 (0.117)				
Penaeus aztecus (3/3)							0.675 (0.120)	0.583 (0.353)			0.285 (0.134)	0.083 (0.117)	0.500 (0.410)	0.416 (0.589)
Callinectes sapidus (7/3)	0.015 (0.021)		0.010 (0.014)	2	0.010 (0.014)	2.750 (3.417)	0.015[5] (0.007)		0.020 (0.014)		0.020 (0.000)	0.083 (0.117)	0.015[5] (0.007)	
Total Organisms	0.830 (0.820)	0.666 (0.942)	4.340 (2.474)	17	1.645 (1.081)	3.750 (2.474)	4.135 (0.431)	2.583 (0.589)	2.845 (2.496)	4.833 (4.478)	2.130[4] (0.367)	0.500 (0.471)	3.735 (1.491)	4.583 (2.239)
No. of Species	10	3	9	3	13	4	15	7	15	6	11	4	16	8
Equitability (1-d)	0.60	0.37	0.22	0.35	0.24	0.26	0.72	0.67	0.46	0.27	0.36	0.50	0.27	0.54
Similarity (C)	0.46		0.50		0.47		0.63		0.57		0.53		0.58	

Table 22
Comparisons of Density Estimates (number per square meter) (± SD) of Nektonic Organisms Collected in Flume Weir and Lift Net Samplers in the *Juncus* Zone of the Natural Marsh Site Over Seven Sampling Periods From November 1992 to May 1994

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Flume	Lift	Flume	Lift[1]	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift
Fundulus grandis (5/1)	0.305 (0.275)	0.250 (0.117)					0.035 (0.021)		0.005 (0.007)		0.010*** (0.000)		0.005 (0.007)	
Fundulus pulvereus (7/7)	0.220 (0.254)	0.083 (0.117)	0.260 (0.141)	11	0.065 (0.007)	0.083 (0.117)	0.075 (0.021)	0.416 (0.589)	0.050 (0.000)	0.166*** (0.000)	0.050 (0.014)	0.166 (0.235)	0.155 (0.007)	0.166 (0.235)
Fundulus similis (3/0)	0.025 (0.021)								0.005 (0.007)		0.010*** (0.000)			
Adenia xenica (7/5)	0.325 (0.318)	0.166 (0.235)	0.020 (0.014)	2	0.120 (0.155)	0.500^5 (0.000)	0.295 (0.148)	0.250 (0.353)	0.055** (0.007)		0.085 (0.007)	0.083 (0.117)	0.230^4 (0.113)	
Cyprinodon variegatus (7/5)	0.135 (0.134)	0.250 (0.117)	0.025 (0.007)		0.010 (0.014)	0.083 (0.117)	0.050 (0.014)	0.083 (0.117)	0.145 (0.007)	0.250 (0.117)	0.025 (0.035)	0.083 (0.117)	0.085* (0.021)	
Poecilia latipinna (6/4)	0.120 (0.127)	0.083 (0.117)	0.035 (0.021)	1	0.010 (0.014)		0.090 (0.056)	0.916 (1.060)	0.315 (0.205)				0.025 (0.035)	0.833 (1.178)
Gambusia affinis (2/0)									0.005 (0.007)				0.015 (0.021)	
Menidia beryllina (5/1)	0.015 (0.007)	0.166 (0.235)					0.100 (0.070)		0.015^5 (0.007)		0.020 (0.028)		0.080 (0.113)	
Gobionellus shufeldti (1/0)											0.005 (0.007)			
Brevoortia patronus (2/0)							0.005 (0.007)						0.005 (0.007)	

(Continued)

Note: All data were corrected to a per square meter basis. Numerals in parentheses below species names indicate frequency of occurrence in samplers (flume weir/lift net). Values for species richness, species equitability (1-d), and coefficients of similarity (C) are also provided. * = Statistically significant at $p \le 0.05 > 0.01$; ** = Statistically significant at $p \le 0.01 > 0.001$; *** = Statistically significant at $p \le 0.001$; [1] = Only one sample was collected (n = 1); [2] = p = 0.06; [3] = p = 0.07; [4] = p = 0.08; [5] = p = 0.09.

Table 22 (Concluded)

Species	Nov. 1992		Mar. 1993		Apr. 1993		May 1993		Sept. 1993		Apr. 1994		May 1994	
	Flume	Lift	Flume	Lift[1]	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift	Flume	Lift
Mugil cephalus (5/1)	0.005 (0.007)		0.005 (0.007)				0.150 (0.183)		0.165 (0.035)	0.083 (0.117)			0.140 (0.197	
Mugil curema (2/0)	0.015 (0.021)								0.170 (0.014)					
Leiostomus xanthurus (3/0)							0.130 (0.183)				0.010 (0.014)		0.130 (0.183)	
Paralichthys lethostigma (1/0)											0.005 (0.007)			
Unid. fish larvae					0.020 (0.014)	0.500 (0.471)	0.010 (0.000)	0.083 (0.117)	0.010 (0.014)		0.025 (0.035)		0.045 (0.063)	
Leptocephalus larvae					0.005 (0.007)						0.005 (0.007)	0.083 (0.117)		
Palaemonetes pugio (7/7)	0.065 (0.091)	0.083 (0.117)	0.650 (0.452)	20	0.070 (0.084)	1.250* (0.353)	0.460 (0.381)	0.666 (0.707)	0.140 (0.141)	1.083* (0.117)	0.375 (0.233)	0.583 (0.353)	0.430 (0.565)	0.583 (0.824)
Penaeus setiferus (1/1)									0.475 (0.021	0.666 (0.471)				
Penaeus aztecus (2/2)							0.335 (0.261)	0.166 (0.235)					0.310 (0.325)	0.166 (0.235)
Callinectes sapidus (4/2)	0.015[5] (0.007)						0.005 (0.007)	0.250 (0.353)	0.010 (0.014)				0.020 (0.000)	0.250 (0.353)
Total Organisms	1.245 (0.403)	1.083 (0.589)	0.995 (0.332)	34	0.300 (0.282)	2.416* (0.117)	1.740 (1.202)	2.833 (1.414)	1.565 (0.021)	2.250 (0.589)	0.625 (0.261)	1.000 (0.707)	1.675 (1.477)	2.000 (2.357)
No. of Species	11	7	6	4	5	4	12	7	13	5	10	4	13	5
Equitability (1-d)	0.73	0.76	0.34	0.41	0.60	0.48	0.73	0.67	0.69	0.51	0.40	0.41	0.74	0.58
Similarity (C)	0.77		0.80		0.88		0.73		0.55		0.57		0.55	

were absent in lift net samples, three are considered resident species (e.g., *Fundulus grandis*), while the remainder are seasonally occurring transient species (e.g., *Brevoortia patronus*) (Table 21). Species richness was consistently higher in flume weir samples (ranging from 2 to 3.3 times). Equitability (1-d) was less different between devices, at times being nearly equal. Similarity was moderately high (C > 0.46) and fluctuated little across all sampling periods (range = 0.46-0.63). As in the *Spartina* zone, the *Juncus* zone flume weir collected a greater number of species overall (18) compared with the lift net (11) (Table 22). Similarly, of the seven species that were absent in lift net samples, three are resident species, while the remainder are seasonally occurring transient species. Species richness and equitability followed similar trends as in the *Spartina* zone, with richness being greater in flume weir samples (ranging from 1.2 to 2.6 times) and equitability differing little between devices in any given sampling period. Similarity was somewhat higher in the *Juncus* zone (C ranging from 0.55-0.88) compared with the *Spartina* zone.

A difference in the suite of species collected by these two devices is suggested by the similarity in the group of species not collected by the lift net samples reported above for both zones, and by similarity in the patterns of species occurrences (i.e., frequency) within each zone. In the *Spartina* zone, 9 of the 14 species common in both sample types had considerably greater frequency (i.e., at least twice) in flume weir samples compared with lift net samples. In the *Juncus* zone, the number of species showing this trend was somewhat less (4 of 11 species common to both devices) and involved a more equal frequency for resident killifishes that are known to preferentially move into higher elevational zones. *Fundulus pulvereus*, *Palaemonetes pugio*, *Penaeus setiferus*, and *Penaeus aztecus* were collected at equal frequencies by both devices. It appears that flume weirs collected a greater diversity of both resident and estuarine transient species compared with lift nets and, therefore, that flume weir samples probably are a more consistent reflection of the nekton assemblage at any given time.

Although total organism density estimates were relatively equal (and for the most part not significantly different) between devices in both zones, differences in density were detected for a number of organisms. Four organisms were collected at significantly greater densities in flume weir samples in the *Spartina* zone including *Fundulus grandis* (May and September 1993, April 1994), *Poecilia latipinna* (May 1994), *Mugil cephalus* (April 1993), and *Leiostomus xanthurus* (April 1994) (Table 21). Four additional organisms had nearly significantly greater densities in flume weirs, including *Adenia xenica* (P = 0.09, May 1993), *Cyprinodon variegatus* (P = 0.06, May 1993), *Palaemonetes pugio* (P = 0.09, April 1994), and *Callinectes sapidus* (P = 0.09, in May 1993 and May 1994). Total organism density approached significance (P = 0.08) in one sample (April 1994). In the *Juncus* zone, four organisms had significantly greater densities in flume weir samples, including *Fundulus grandis* (April 1994), *Fundulus similis* (April 1994), *Adenia xenica* (September 1993, approaching significance at P = 0.08 in May 1994), and *Cyprinodon variegatus* (May 1994). Two other organisms had greater densities in

flume weirs, including *Menidia beryllina* (P = September 1993) and *Callinectes sapidus* (P = 0.09, November 1992). Two organisms did have significantly higher densities in lift net samples in the *Juncus* zone, including *Fundulus pulvereus* (September 1993) and *Palaemonetes pugio* (April and September 1993), with *Adenia xenica* having higher densities there in April 1993 (P = 0.09). Total organism density was also significantly higher in this zone in April 1993.

Mammals and Avifauna

The rice rat, *Oryzomys palustris palustris*, was the only small mammal collected in traps in either zone or marsh. A total of 14 rats were trapped over a 3-day period in November 1992 (two in the natural *Juncus* and one in the constructed *Juncus* on Day 1; one in the natural *Juncus* and two in the constructed *Juncus* on Day 2; one in the natural *Juncus*, two in the constructed *Juncus*, three in the natural *Spartina*, and two in the constructed *Spartina* on Day 3). Although rats were trapped in each zone in each marsh area, collections varied depending on the tidal condition. No rats were caught in either the natural or constructed *Spartina* zones on the first two nights. This is believed due to the flooded conditions of the marsh at night during this period (i.e., the single high tide occurred on each night between 20:00 and 24:00 hr), thereby limiting the distribution of these animals to the higher marsh areas (i.e., *Juncus*) during their period of highest activity (nighttime). On the third night, however, a strong north wind kept the tide from rising onto the marsh and, thereby, allowed access to these animals. Five rice rats were collected in the *Juncus* zones of both marshes over a 2-day period in March 1993 (one in the natural *Juncus* and two in the constructed *Juncus* on Day 1; two in the natural *Juncus* on Day 2). High tidal conditions during the nighttime activity period for this species probably explains the lack of captures in the low-elevation *Spartina* zone. Evidence of herbivory by the rice rat was evident in both zones of both marshes in the winter months when many of its other food items are not available (e.g., fiddler crabs). Small piles of shredded leaves of both *Spartina* and *Juncus* were commonly seen on the marsh surface, indicating that these animals forage in both elevational zones on both plant species.

The use of these marshes by other mammal species was also recorded through the presence of tracks, scat, trails, and sightings. Scat of marsh rabbit, *Sylvilagus palustris palustris*, raccoon, *Procyon lotor varius*, and muskrat, *Ondatra zibethicus rivalicius*, were commonly encountered in both zones of both the natural and constructed marshes, particularly on the elevated boardwalks that surrounded the flume weirs used to sample nekton. Tracks and feeding areas (i.e., broken molluscs shells) of raccoon were often observed in both areas. Numerous trails and one muskrat den were observed in the natural area; trails, but no dens, were observed for this species in the constructed area. Tracks of white-tailed deer were commonly seen along with occasional sightings (at night) along the upper margin of the constructed

marsh (i.e., along the buffer area). Although not seen in either the natural or constructed marshes, the nutria, *Myocastor coypus bonariensis*, is known to be present in nearby marshes and may very well be present at both sites.

The suite of bird species recorded from both marshes (Table 23) includes a combination of both resident species, which are known to feed and/or nest in tidal marshes, as well as a number of seasonally occurring species that used the marsh primarily for feeding (overwintering species). The clapper rail,

Table 23
Bird Species Observed in the Natural and Constructed Marsh Sites, Including Relative Abundance and Activities Observed or Presumed (Nesting was presumed for resident species, with actual sightings of nests indicated with an asterisk)

Species	Marsh Area Observed	Activity
Resident Marsh Species		
Clapper Rail, *Rallus longirostris*	Common in both areas	Feeding, nesting (* *Juncus*)
Marsh Wren, *Cistothorus palustris*	Common in both areas	Feeding, nesting
Seaside Sparrow, *Ammospiza maritima*	Common in both areas	Feeding, nesting
Least Bittern, *Botaurus lentiginosus*	Occasional in both areas	Feeding, nesting
Mottled Duck, *Anas fulvigula*	A pair in natural area	Feeding, nesting
Resident Wading Species		
Great Blue Heron, *Ardea herodias*	Common in both areas	Feeding
Great Egret, *Casmerodius albus*	Common in both areas	Feeding
Snowy Egret, *Egretta thula*	Common in both areas	Feeding
Willet, *Catoptrophorus semipalmatus*	Common in both areas	Feeding, courtship, nesting
Resident Species That Use Marshes/Estuarine Habitats		
Red-Winged Blackbird, *Agelaius phoeniceus*	Common/upland edges	Feeding, nesting (* both marshes)
Belted Kingfisher, *Megaceryle alcyon*	Common (most in const. area)	Feeding
Osprey, *Pandion haliaetus*	Common over both areas	Feeding
American Kestrel, *Falco sparverius*	Common over const. area	Feeding
American Coot, *Fulica americana*	Tidal creeks of both areas	Feeding
Seasonal/Overwintering Species		
Sora, *Porzana carolina*	Occasional in both areas	Feeding
Red-Tailed Hawk, *Buteo jamaicensis*	Common over both areas	Feeding
Red-Shouldered Hawk, *Buteo lineatus*	Common over both areas	Feeding
Northern Harrier, *Circus eyaneus*	Common over both areas	Feeding
Sanderling, *Calidris alba*	Common in const. area	Feeding
Horned Grebe, *Podiceps auritus*	Tidal creeks of both areas	Feeding
Pied-Billed Grebe, *Podilymbus podiceps*	Tidal creeks of both areas	Feeding
Hooded Merganser, *Lophodytes cucullatus*	Tidal creeks in const. area	Feeding

marsh wren, and seaside sparrow were observed or heard commonly in both zones of both marshes and by their active courtship displays and activity during the spring and summer months, were presumed to be nesting throughout both areas. Clapper rail chicks were flushed from the edge of the tidal creek near the mouth of the constructed marsh in early summer 1992 (during preliminary reconnaissance of the site), and one abandoned clapper rail nest was encountered in the natural *Juncus* marsh in late summer of 1993. A pair of mottled ducks were seen frequenting the same general vicinity in the natural marsh area over a 4-day period during the spring of 1993 and were presumed to be preparing a nesting site. At least two pairs of willets were also seen actively courting in the vicinity of both mashes during this same period and were also assumed to have nested nearby (likely in a nearby high-marsh area within the natural marsh).

Several species of wading birds were commonly observed to be feeding along the tidal creeks in both marshes, particularly the great blue heron and snowy egret. Because of the more open nature of the low-marsh area in the constructed marsh (i.e., unvegetated areas along the tidal creek that were denuded by Hurricane Elana in 1995), wading birds were somewhat more abundant there compared with the natural marsh. Kingfishers, osprey, and American kestrel were also commonly seen flying about and hunting over both areas. Red-winged blackbirds nested heavily in the shrubs (i.e., *Baccharis haminifolia*) located in the buffer zone of the constructed marsh and along the borrow channel that supplies tidal water to the constructed marsh and were seen feeding frequently in both marshes. Both marshes were used as foraging grounds for the suite of overwintering species listed in Table 23.

6 Discussion

The constructed marsh evaluated by this study was designed with two major goals in mind. The first goal was to create a system with maximal habitat heterogeneity, by incorporating a grade in elevation across the site and thus creating multiple elevational zones. The second goal was to maximize the exchange of water to and from the site, through the construction of a tidal creek. Both of these design factors were used in hopes of maximizing the success of the mitigation, as well as the functional capacity of the resulting marsh. The choice of the method of construction (i.e., the grade-down of what had been upland habitat) was more a case of necessity (using available onsite acreage), rather than choice, and was made without the benefit of more recently reported limitations associated with the use of this method of constructing marshes (Moy and Levin 1991).

Variation from the ideal recreation of proper elevational zones was detected in this study, however, and does help to explain observed differences in patterns of some biotic components discussed below, as may the predictable (and subsequently observed) differences in sediment characteristics associated with grade-down marshes. Although every effort was made to construct the site to reflect the same relative positions of each elevational zone, differences in elevation were subsequently detected between the natural and constructed sites (Table 1). The *Spartina* zone of the constructed marsh was found to be as much as 16.4 cm lower in elevation and was subsequently flooded more frequently and for longer durations compared with the natural marsh. As discussed below, however, this lower elevation appears to enhance some functions. The difference in elevation between the *Juncus* zones of both marshes was much lower (<4 cm) and is likely to have had relatively little effect on the biotic components of this zone.

Physical parameters

While the sediment characteristics of the constructed marsh were quite different from the natural marsh (Table 2) and clearly reflect the sandy nature of what once was subsoil of a terrestrial habitat, there is some indication that

finer materials have been deposited in the lower elevational zones of the constructed marsh. This conclusion is based on the comparison of textural characteristics between zones in this marsh. First, it is logical to assume that the textural nature of the high-marsh zone in this marsh has changed little since construction. This assumption is based on the known irregular and infrequent flooding frequency of this zone, which might transport fine-grain material for deposition there, and the observation that this zone is scoured by runoff draining the adjacent buffer zone during heavy rain events. If these assumptions are true, the higher quantities of finer grained materials observed in the two lower elevational zones (Table 2) would logically represent a departure from the "parental" nature of the high-marsh zone sediment. It is assumed that these accumulated materials were transported in by tidal exchange, with some deposition possible from the washing of sediments from the buffer area. The flocculent nature of the upper portion (5 cm) of the sediments observed in the low-marsh *Spartina* zone of this marsh also supports this conclusion and may in fact represent the cumulative accumulation of sediments since construction. The sediment layer below 5 cm is sandy and compacted, as it is in the higher marsh zone. Plant stems appear to be facilitating deposition of sediments in the low-marsh zone, compared with the more compacted nature of the sediments of the open, unvegetated portions of this area. Given this apparent trend toward accumulation of sediments in this zone, it is likely that the relative elevation of the zone will rise to eventually offset the observed difference between the elevation of this marsh compared with the natural marsh (Table 1).

Biotic Components

Despite the observed differences in elevation and sediment texture of the natural versus constructed marshes, most of the biotic components of the constructed marsh were at least comparable with, and sometimes greater, than those of the natural marsh. Those components that were different between marshes can, in most cases, be attributable to either elevation or to differences in associated hydrologic factors, such as the higher flooding duration of the low-marsh zone of the constructed marsh. The effects of sediment texture on these components are much more difficult to ascertain, given the general lack of knowledge of how sediment parameters affect these components. Regardless of possible explanations for observed trends between marshes, the comparisons of the major biotic components can still be used to test the basic hypothesis that these components are of a similar nature (qualitative) and quantity (i.e., not significantly different) to those of the natural marsh.

The vegetative characteristics of both areas were similar overall (Tables 3 and 4). The only significant differences in the *Spartina* zone was the greater height of plants in the constructed marsh, and although differences were detected in several plant parameters in the *Juncus* zone of the natural marsh in 1992, they were only slight and not different the following year. *Distichlis spicata* appeared to be somewhat more prevalent in the constructed *Juncus* zone, but still represented a relatively minor component overall. As expected,

belowground biomass was lower in the constructed marsh (Table 5), but is logically a function of the sites' age and should increase with time. These trends are similar to those reported for multiaged zones of a constructed marsh in South Carolina (LaSalle, Landin, and Sims 1991).

The small macroinfaunal assemblages of both zones in both marshes were also only slightly different overall. In the case of small macrofauna, assemblages in the constructed zones seemed to support a somewhat greater diversity of taxa, as evidenced by the greater total number of taxa and the number of taxa unique to this marsh (Table 6). Although the assemblages did differ in terms of total numbers of taxa and the suites of dominant taxa on a seasonal basis, similarity between marshes in either zone was still relatively high. Overall, *Spartina* zone assemblages were more similar between marshes (Tables 7-9) compared with those in the *Juncus* zone (Tables 10-12), and as would be expected, similarity was typically higher between the three assemblages studied within both constructed marsh zones. The constructed marsh did also tend to support significantly greater numbers of organisms compared with the natural marsh.

The large macrofaunal assemblages, on the other hand, showed somewhat greater differences between marshes depending on the taxa considered (Table 13). Although abundances of key taxa, such as *G. demissa* (both zones) and *L. irrorata* (*Spartina* zone), were higher in the natural marsh, other taxa were found at higher levels in the constructed site (*N. usnea* and *L. irrorata* in the *Juncus* zone). Other taxa, such as *C. virginica* and *C. pliculosa*, were restricted to the artificially low-elevation *Spartina* zone in the constructed site, a preferred habitat for these species. Overall, the *Juncus* zone of the constructed marsh supported a more similar assemblage of large macrofauna compared with that of the natural marsh.

Fish assemblages were quite similar between the natural and constructed marshes for both zones studied (Table 14). Assemblages were composed of a similar suite of fishes and shellfish, including a suite of year-round resident species (e.g., grass shrimp and killifishes) and the seasonally occurring juveniles of estuarine transient species (e.g., spot, brown, and white shrimp). The grass shrimp was the numerically dominant organism overall. Trends in total organism densities favored the constructed marsh in both zones, but the trends for species was different for each zone. In the *Spartina* zone, resident species of fishes tended to be more abundant in the natural marsh, while estuarine transient fishes and shrimp were typically found at higher levels in the constructed marsh. The opposite trend was true for the *Juncus* zone. These data suggest that the lower than normal elevation of the *Spartina* zone in the constructed marsh was a more favorable habitat for estuarine transient organisms that may have responded to the more frequent and longer duration of flooding at this site. Rozas and Reed (1993) reported the same trend for marshes undergoing submergence in Louisiana. These organisms do not typically travel very far into densely vegetated marshes where tidal channels are not present (Rozas and Reed 1993) and may, therefore, find the conditions in the constructed low-marsh zone more attractive. This same reasoning may also

explain the lower densities of transients in the higher level *Juncus* zone of the constructed marsh in that these organisms may preferentially remain in the lower zone.

Finally, there appears to be very little difference between the use of both marshes by most mammals and birds. Rice rats and other larger mammals appear to actively utilize both marshes, with differences in use being limited to the apparently greater use of the constructed marsh by deer (along the upland border and salt pannes). Both sites were actively used by a wide variety of resident birds that used these marshes for both feeding and nesting and seasonally occurring species of birds that overwinter in the area. If anything, the more open nature of the low-marsh zone in the constructed marsh appeared to attract greater use of this site by wading birds.

Effect of Tidal Creek on Biota

The degree to which the tidal creek affected the functional level of the constructed marsh was tested primarily through the comparison of the nekton assemblages in the midelevation *Juncus* zone along the length of the site. The effect on the benthic assemblages along this creek may also be used to ascertain its value to this component as well. For both assemblages, it appears that the creek did allow greater access and support to a greater portion of the site by allowing for adequate exchange of tidal water. Total nekton densities were greater in the upper area in four of the seven periods sampled, suggesting that the creek does serve as a conduit for access of these organisms into the marsh (Table 19). As with the nekton assemblages collected in flume weirs, the assemblages from lift nets were composed of a similar suite of fishes and shellfish, with year-round resident species (e.g., killifishes and grass shrimp) dominating most samples. There were some differences, however, in the use of upper versus lower creek sites by selected taxa that may reflect and suggest their species-specific habitat use patterns.

The killifish, *F. pulvereus*, and the grass shrimp, *P. pugio*, were the dominant resident organisms in both areas, but differed in their relative use of the upper and lower creek. *Fundulus pulvereus* tended to be more abundant (but not significantly so) in the upper creek area in most samples (four of seven), while *P. pugio* showed trends of use of both areas. *Palaemonetes* was significantly more abundant in the lower marsh in 2 months in the spring of 1993, but was found at higher densities in the upper marsh in one sample in the same period of the following year (1994). The apparently greater use of the upper creek area by *Fundulus* may reflect the trend for killifish to preferentially move as far into open marshes as possible. Killifish preferentially feed in intertidal marshes (Rosas and LaSalle 1990) and are known to follow the leading edge of flooding waters as high up into a marsh as they are able (Rozas and Reed 1993). This trend also applies to their penetration into small creeks and rivulets of marsh as the tide rises (Rozas and Odum 1987). Estuarine transient species of nekton, on the other hand, typically utilize the edge of marshes, penetrating less than 5 m from the nearest subtidal refuge

(Rozas and Reed 1993) and probably the lower portions of tidal creeks. In the present study, brown shrimp, *P. aztecus*, were found only in the lower creek area, while white shrimp, *P. setiferus*, appeared to travel further up the creek.

The effect of the tidal creek on the benthic macrofauna of the constructed marsh was much less apparent than for nekton in that there were no obvious trends in density patterns of benthic organisms across the site. All three areas sampled along the creek supported similar overall assemblages of macrofauna, which at a minimum suggest that the creek does not hamper and may actually facilitate the development of this component throughout the marsh. Overall, therefore, it appears that the tidal creek served to improve the overall quality of the constructed marsh by allowing greater access of the site by nekton and, at a minimum, allowing for development of comparable benthic assemblages across the marsh.

Flume Weir/Lift Net Comparisons

The difference in total area sampled by these two devices would be enough to predict the observed differences in both the types and numbers of organisms collected (Tables 21 and 22). A flume weir encloses 16.6 times as much marsh surface area as does a lift net, which as Kneib (1991) pointed out, is important toward reducing the "area-to-edge" effect. As designed and used by Rozas (1992), however, the smaller lift net was used to investigate smaller scaled habitat use patterns of nekton in elevational zones that were often too narrow to accommodate a larger device (common in Gulf Coast marshes). Used in the same marsh (as in this study), therefore, a flume weir would enclose a larger proportion of a given vegetative zone and would tend to sample nekton that were distributed across a wider area within the zone. A lift net, on the other hand, could be positioned and would sample potentially different assemblages of nekton within the same zone (some species of nekton are known or believed to penetrate to varying degrees into marshes).

In the present study, the lift nets used were placed with their centers at the same relative position within the zone as that of the nearby flume weir, which would equate to them being placed at, and sampling from, the center of a flume weir. The portion of this area sampled by the lift net would, therefore, be located as much as 6 to 8 m further into the zone than the leading edge and the back edge of the flume weir. As placed in this study, therefore, a lift net may completely miss taxa of nekton that do not penetrate deeply into marshes (within the first 2 to 5 m) or may underestimate taxa that are known to penetrate well into the marsh (e.g., killifishes), but would have moved past the relative position of the net when it was triggered (at high slack tide). The data collected in this study seems to support this conclusion, given the list of taxa that were not collected by the lift net. In the *Spartina* zone, this group included the juveniles of five species of estuarine transient nekton that are either known or suspected of using only the edges of marshes (*B. patronus*,

M. undulatus, *C. nebulosus*, *P. lethostigma*, *S. foetens*), but also included at least three species of resident marsh fishes (*F. grandis*, *G. affinis*, *G. shufeldti*) that are known to move deeply into marshes (and presumably past the area of the marsh sampled by the lift net). In the *Juncus* zone, four estuarine transient taxa were not collected (*B. patronus*, *M. curema*, *L. xanthurus*, *P. lethostigma*) along with three resident species (*F. similis*, *G. affinis*, *G. shufeldti*). Differences in the patterns of relative frequency of occurrence for taxa that were common in both sample types (i.e., greater frequency in flume weirs) also support the conclusion that flume weirs sampled a more diverse assemblage of nekton. Despite the qualitative differences in the assemblages sampled by these two devices, however, total organism densities estimates were relatively equal for both devices in both zones.

It appears, therefore, that flume weirs collect and describe a more diverse assemblage of nekton compared with lift nets. For the purposes of the present study, this superior performance for each zone as a whole (i.e., the entire width of the *Spartina* zone and a large portion of the *Juncus* zone) allowed for a more thorough evaluation of the key question being addressed (i.e., were the nekton assemblages equal for constructed versus natural marshes). Although not analyzed in this report, however, it is likely that a similar conclusion of this overall question would have been reached had only lift nets been used.

Based on the above discussion of the relative portion of the marsh surface sampled by each device, it is worth noting some key pros and cons of using each device that should be considered when choosing the method of sampling nekton on the marsh surface. While flume weirs are much larger and, based on this study, present a better picture of the nekton assemblages compared with lift nets, it must be remembered that the area sampled is of a much larger "proportion" of a given zone or marsh compared with that sampled by a lift net. In some cases, particularly along the northern Gulf coast, a flume weir would simply not fit within some vegetative zones. Low-marsh *Spartina* zones, for example, may be quite narrow (1 to 2 m) or of small overall size in this region of the country and could not be sampled with a flume weir. Flume weirs could, however, be easily placed within the more expansive mideleva-tion *Juncus* zone in this region. The opposite situation would be true for the Atlantic coast where low marsh dominates. As noted in this study, it was difficult to locate a large enough patch of low marsh in the natural area in which a flume weir could be placed. When comparing multiple zones of a marsh or different marshes, flume weirs would, therefore, be the device of choice only if enough space was available to accommodate a flume weir in each site. Lift nets, on the other hand, would be more appropriate for comparing multiple zones that may include one or more that are too small for supporting the larger sized flume weirs. Lift nets would also be useful for evaluating questions about subportions of selected vegetation zones (e.g., the lower portions, midportions, and/or higher portions of a given zone).

Flume weirs are also more expensive to make and install compared with lift nets, which may limit the number that can be built and sampled. Material costs for a flume weir in this study was about $850 compared with the

$200 cost of a lift net. These figures do not include the labor costs required to build and install the numerous wooden components of a flume weir (e.g., screen panels, boardwalk supports). Each flume weir built for this study required an estimated 3 man-weeks of labor to build and place in the marsh (about a week of work on parts and a week in the field by one full-time and one half-time person). Lift nets, on the other hand, required less than 1 man-day of time to prepare and install (two persons could prepare and install up to two per day). Because of their large size and relative costs, fewer flume weirs are likely to be used in most studies. It is also difficult to consider the use of multiple flume weirs to collect "replicate" samples using multiple devices. Lift nets would be a much more appropriate approach for collecting replicates using multiple devices. The use of replicates based on tidal events, as in this study, is of course an alternative approach to collecting replicate samples.

In summary, flume weirs, although more expensive, do appear to be a superior device for sampling nekton in marshes, assuming there is adequate space for their placement. Costs and size may, however, limit their use. Lift nets may be more appropriate for use when multiple sampling devices are required for addressing microhabitat questions. Some of the drawbacks associated with a lift net's small size could be overcome if "replicate" nets are used.

Summary

After 7 years, the constructed marsh studied here appears to support comparable biotic components with that of a nearby natural marsh, despite differences in the relative elevation of the low-marsh zone (lower in the constructed marsh) and continued difference in the sediment texture related to the method of construction (grade-down of upland). Both sites support similar plant, macrobenthic, and nekton assemblages and were used by a similar suite of mammals and birds. Nekton use of the lower than normal low-marsh zone in the constructed marsh was higher than that of the natural marsh, apparently in response to the associated higher flooding frequency and duration. Sedimentation appears to be proceeding in the constructed marsh, particularly in the more frequently flooded low-marsh zone, which will likely continue to contribute fine-grain materials. The tidal creek appears to have facilitated the development of comparable plant and benthic assemblages across the constructed site and also allows for the use of the entire site by nekton. Flume weirs allowed for a more detailed description of the nekton assemblages of the marsh compared with lift nets, but size and cost considerations limit their general applicability to studies of this type.

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1996

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Assessing the Functional Level of a Constructed Intertidal Marsh in Mississippi

5. FUNDING NUMBERS

6. AUTHOR(S)
Mark W. LaSalle

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Coastal Research and Extension Center
Mississippi Agricultural and Forestry Experiment Station
Mississippi State University, Biloxi, MS 39531

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000;
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Technical Report
WRP-RE-15

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Detailed assessments of the major biotic components of a 25-acre (10.12-ha) constructed marsh were undertaken 7 years after it was constructed by grading down uplands. The marsh consisted of low-elevation (*Spartina alterniflora*), midelevation (*Juncus roemerianus*), and high-elevation (salt panne) zones with a centrally located creek included to facilitate water exchange across the site. The predominantly sandy texture of the sediments in the constructed marsh (sand >80 percent) was substantially different from that of nearby natural marshes (sand <10 percent), reflecting the grade-down nature of the site. The elevation of the low-marsh zone of the constructed marsh was also different (16.6 cm lower) from that of the natural reference site, resulting in greater flooding frequency and duration in this zone. Despite physical differences, the constructed marsh supported similar vegetative, benthic, and nektonic assemblages compared with the natural reference. Mammal and avifaunal use was also similar between sites. Nekton use of the constructed low-marsh *Spartina* zone was higher than that of the natural marsh, apparently in response to the associated higher flooding frequency and duration. Sedimentation appears to be occurring in the constructed marsh and will likely continue. The tidal creek appears to have facilitated the development of comparable plant and benthic assemblages across the constructed site and also allows for the use of the entire site by nekton. Sampling with flume weirs provided a more detailed description of the nekton community of the marsh compared with lift nets.

14. SUBJECT TERMS

Aquatic productivity	Coastal marsh	Physical components
Biomass	Constructed wetlands	Restoration
Biotic components	Functional capacity	Sediment

15. NUMBER OF PAGES
74

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

☆U.S. GOVERNMENT PRINTING OFFICE: 1996-532-181/40022